the distance of centers, which is the quantity to be measured, being fifty times greater than the mean effect of parallax at the different stations, the latter will appear as a difference between two large quantities, and any error affecting the whole distance measured in a given ratio will affect the parallax in a ratio fifty times as great. To estimate the degree of accuracy which it is desirable to obtain, we should know what degree of accuracy a measure on the photographic plate admits of. This is a point on which we have no exact published information, but it is understood that the measures of the photographs of the eclipse of 1869 indicate that the probable error of a negative as measured is but a small fraction of a second of arc. We have some reason to hope that the probable accidental error of a determination of the distance of centers from a single negative will be less than half a second. It is probable that two hundred negatives can be taken at each station. Granting this, we may hope that the probable accidental error of the mean of all the measures at one station may be as small as $0''.03$. It is desirable that the constant errors peculiar to the station or the instrument should be but a fraction of this amount, say, $0''.02$. The least distance of centers being, on the average, about $800''$, it is desirable that the measures should not be affected

CIRCULAR

PREPARED BY DIRECTION OF THE

HON. WM. BALLARD PRESTON,

SECRETARY OF THE NAVY,

IN RELATION TO THE

ASTRONOMICAL EXPEDITION TO CHILE.

BY LIEUT. M. F. MAURY, U. S. N.,
Superintendent of the National Observatory.

WASHINGTON:
C. ALEXANDER, PRINTER,
1849.

Madras Observatory
From Lieut. Gilliss. U.S. —

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TO THE FRIENDS OF ASTRONOMICAL SCIENCE.

In the year 1847 Dr. Gerling, of Marburgh, suggested that a new determination of the solar parallax might be obtained by observations upon Venus at and near her stationary periods, provided these observations were made at points far removed from each other.

In 1847–8, the American Philosophical Society and the Academy of Arts and Sciences recommended to the Secretary of the Navy that an astronomical expedition be sent to Chile for the purpose of making, according to Dr. Gerling's plan, observations there upon Venus in connexion with the National Observatory at Washington.

By an act of Congress, approved August 3d, 1848, the Secretary of the Navy was directed to cause these observations to be made.

Being thus authorized by the National Legislature, and that nothing, which is calculated to impart interest to the undertaking or to give value to its results, may be omitted on the part of the American Government, I am directed by the Hon. Wm. Ballard Preston, Secretary of the Navy, to announce to the friends of Science the objects and plan of the expedition, and to invite Astronomers generally to lend it their co-operation by making, in so far as it may be practicable and convenient for each one to make, a series of corresponding observations.

The Expedition has been fitted out on a scale commensurate with the objects in view. All the means and facilities for it which Congress has placed at the disposal of the Executive, have been afforded to it by the Secretary of the Navy. Reposing special trust and confidence in the zeal and ability of Lieut. J. M. Gilliss, U. S. N., he has appointed that officer to the charge of it; other officers of the Navy have been detailed to accompany it as assistants, Passed Midshipmen A. McRae and Henry C. Hunter, who are to accompany it, have been stationed at the National Observatory for the requisite and previous training. The necessary instruments have been procured for the Expedition, and suitable buildings to serve as an Observatory in Chile have been prepared in Washington. They are wooden structures, and will be taken to pieces and shipped to Valparaiso in the course of a few days.

The principal Astronomical Instruments which the Expedition will carry with it, are two Telescopes, Equatorially mounted, a Meridian Circle, a Clock and three Chronometers.

The larger Telescope is an eight and a half foot Refractor. It has an object glass by Fitz, of New York, that affords a clear aperture of six inches and a half. It is fitted with clock-work by Wm. Young of Philadelphia, and by him provided with a Micrometer adapted both for differential measurements and for measurements of angle of position and distance.

The other Telescope is a five foot Achromatic by Fraunhoffer. It, also, has been equatorially mounted and fitted with a Micrometer, by Young of Philadelphia.

The Meridian Circle ... by P... ... M... ... of four and one third inches, ... [illegible] ... minutely divided, and provided each with two ... Micro...

The Series of Astronomical observations ... [illegible] ... invited, will consist of differential ... [illegible] ... upon Venus and Mars, with certain stars along their path.

The observations upon Venus ... [illegible] ... tial measurement upon that planet ... [illegible] ... 1850 and 1852.

In like manner, Mars will be compared with ... [illegible] ... in 1849 and 1852. The object of these observations upon the pl... [illegible] ... parallax.

To facilitate the observations and to secure concert of ... [illegible] ... the world, may, in observing the planets, always use the ... [illegible] ... the accompanying charts and tables.

Charts No. 1 to 5, inclusive, refer to Venus; 6 and 7 to Mars.

They show the approximate places of the planets ... [illegible] ... tenth magnitude, near their path.

In some parts of the paths of the planets, ... which ... [illegible] ... of comparison, special observations have been made with the ... [illegible] ... stars, whose approximate places have been thus obtained, are mapped ... [illegible]

Tables 1 and 2 contain the Ephemeris of the planets and the ... [illegible] ... comparison for each day, and quote its magnitude with its approximate ... [illegible]

The stars marked W. C. are from the unpublished observations of the Washington Catalogue, as they have not undergone their final reduction, their declinations are only given to the nearest 10". The ... are designated by the initials or name of the Catalogue from which they are taken.

In the Ephemerides of the two planets and the neighbouring ... [illegible] ... country of the year for which the Ephemerides are calculated, ... [illegible] ... to give the place of the stars with accuracy sufficient merely to ... [illegible] ... each star which all observers are requested to ... [illegible]

It is requested that those who may ... the ... [illegible] ... planets also, both for R. A. and Dec., at their meridian p...

... observations ... proposed by Lieut. Gilliss ... [illegible]

... of the Ephemeris of Mars, ... [illegible]

day, will be commenced ... [illegible]

contained ... [illegible]

... [illegible]

The Meridian Circle is by Pistor and Martins The object glass of the Telescope has an aperture (clear) of four and one-third inches, with a focal length of six feet The circles are thirty-six inches diameter minutely divided, and provided each with two reading Microscopes

The Series of Astronomical observations, in which the co-operation of other observers is more especially invited, will consist of differential measurements, during certain portions of the years 1849, '50, '51 and '52 upon Venus and Mars, with certain stars along their paths

The observations upon Venus which will most command the attention of the Expedition, will be differen-tial measurements upon that planet, in the morning and evening, while it is near the inferior conjunctions o 1850 and 1852.

In like manner, Mars will be compared with its neighboring stars near the times of opposition of that plane in 1849 and 1852 The object of these observations upon this planet, is a more accurate determination of it parallax

To facilitate the observations and to secure concert of action, so that the co-operators, in whatever part o the world, may, in observing the planets, always use the same stars of comparison, Lieut. Gilliss has prepare the accompanying charts and tables.

Charts No. 1 to 5, inclusive, refer to Venus; 6 and 7 to Mars.

They show the approximate places of the planets from day to day relatively to the stars, down to th tenth magnitude, near their path.

In some parts of the paths of the planets, along which published catalogues do not afford proper sta of comparison, special observations have been made with the large Refractor of the National Observatory, th stars, whose approximate places have been thus obtained, are mapped down along the planet's path.

Tables 1 and 2 contain the Ephemeris of the planets, and the stars of comparison. They give the star comparison for each day, and quote its magnitude with its approximate mean place only

The stars marked W C are from the unpublished observations of the Washington Catalogue; as the have not undergone their final reductions, their declinations are only given to the nearest 10″. The other sta are designated by the initials or name of the Catalogue from which they are taken

In the Ephemerides of the two planets and their neighboring stars, the mean places of the stars for 1 January of the year for which the Ephemerides are calculated, are given The object of such Ephemerid is to give the place of the star with accuracy sufficient merely to leave no doubt as to the identity of the part cular star which all observers are requested to use during the observations for the day thereby provided for

It is requested that those who may have the goodness to co-operate in these observations will observe th so, both for R A and Dec, at their meridian passage.

rder of observations, proposed by Lieut Gilliss, is this —

the term of the Ephemeris of Mars, differential measurements upon that planet, and the star or the day, will be commenced at two hours after the passage of the planet across the meridian nd be continued for one hour and a half after the star and planet shall have passed the meridia of Washington, observing and comparing with the star, the North and South Limb of the planet alternately

Both the planet and its star of comparison will also be observed, with the Meridian Circle, at their transit across the meridian of the Observatory in Chile.

The same course is proposed to be pursued, at meridian transit, with regard to Venus and her star of comparison.

Lieut. Gilliss proposes to commence the differential observations upon Venus and her star of comparison, as given in the Ephemeris, as early in the evening and morning, and to continue them as long as the light of the Sun and the conditions of the atmosphere may admit.

Owing to the absence of stars of sufficient magnitude within 15° of the Sun, an omission is made in the Ephemeris during the time that the planet will be within that distance of the Sun. It is proposed, during such intervals, to rely exclusively on meridian observations, both at the Observatory in Chile and elsewhere.

The precise place in Chile, at which the Observatory is to be erected, will not be decided upon until the arrival there of the Expedition.

Those Astronomers, who are disposed to forward the objects of the Expedition so far as to co-operate with it in conducting an auxiliary Series of observations, will perceive that the results of their labors will be enhanced by using, wherever practicable, the stars of comparison which Lieut. Gilliss has selected, and which are given in tables 1 and 2, and by following generally the plan of observations proposed by him and herein explained.

Each co-laborer is requested to send annually, to the Superintendent of the National Observatory, at Washington, his observations, with an account of the instruments with which they were made, together with such other information in relation thereto as is necessary to a full understanding and appreciation of them and the results arising therefrom.

M. F. MAURY,

Lieut. U. S. Navy.

June, 1849.

TABLE I.

EPHEMERIS

OF

VENUS AND HER STARS OF COMPARISON,

DURING

THE STATIONARY PERIODS OF THE PLANET,

IN

1850 & 1852,

BY LIEUT. J. M. GILLISS, U. S N

DATE		OBJECTS TO BE OBSERVED		MAG.	RIGHT ASCENSION			[illegible]		
					H	M				
1850	October 19	Venus			16	39	[illegible]	26	[illegible]	1
		H. C.		7.8	16	40	[illegible]	26	[illegible]	[illegible]
	20	W. C.		8	16	42	[illegible]	26	24	[illegible]
		Venus			16	43	[illegible]	26	40	1
	21	Venus			16	[illegible]	13	[illegible]	49	[illegible]
		W. C.		8	16	47	10	26	[illegible]	[illegible]
	22	Venus			16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		W. C.		8	16	[illegible]	[illegible]	[illegible]	1	[illegible]
	23	Venus			16	[illegible]	11	[illegible]		11
		W. C.		8	16	[illegible]	[illegible]	26	[illegible]	10
	24	Venus			16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		W. C.		9	16	[illegible]	11	[illegible]	11	[illegible]
	25	Venus			17	1	[illegible]	27	19	13
		W. C.		6.7	17	4	[illegible]	[illegible]	[illegible]	10
	26	W. C.		6.7	17	4	[illegible]	[illegible]	[illegible]	10
		Venus			17	5	31	[illegible]	[illegible]	24
	27	Venus			17	9	2	[illegible]	31	4
		W. C.		7.8	17	10	13	27	36	10
	28	W. C.		7.8	17	10	13	27	36	10
		Venus			17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	29	W. C.		7.8	17	10	13	27	36	10
		Venus			17	[illegible]	[illegible]	[illegible]	40	[illegible]
	30	W. C.		8.9	17	12	[illegible]	[illegible]	[illegible]	[illegible]
		Venus			17	19	12	[illegible]	[illegible]	[illegible]
	31	Venus			17	[illegible]	28	[illegible]	4	[illegible]
		W. C.		7.8	17	30	[illegible]	[illegible]	4	[illegible]
	November 1	Venus			17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Lacaille	7371	7	17	28	[illegible]	[illegible]	[illegible]	[illegible]
	2	Venus			17	[illegible]	16	[illegible]	[illegible]	[illegible]
		Lacaille	7371	7	17	28	[illegible]	[illegible]	[illegible]	[illegible]
	3	Lacaille	7371	7	17	28	[illegible]	[illegible]	[illegible]	[illegible]
		Venus			17	31	[illegible]	[illegible]		[illegible]
	4	Lacaille	7371	7	17	28	15	[illegible]	[illegible]	[illegible]
		Venus			17	34	[illegible]	[illegible]	[illegible]	1
	5	Venus			17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		W. C.		7.8	17	43	[illegible]	[illegible]	1	[illegible]

TABLE I—*Ephemeris for observing* Venus *in* 1850

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			SOUTH DECLINATION		
						H	M	S	°	′	″
1850	November	6	Venus			17	40	23	27	58	21
			W C		7 8	17	43	53	28	1	0
		7	Venus			17	43	4	27	58	14
			W C		7 8	17	43	53	28	1	0
		8	W C		7 8	17	43	53	28	1	0
			Venus			17	45	38	27	57	41
		9	Venus			17	48	6	27	56	38
			W C		8	17	52	23	27	52	0
		10	Venus			17	50	28	27	55	6
			W C		8	17	52	23	27	52	0
		11	W C		8	17	52	23	27	52	0
			Venus			17	52	42	27	53	5
		12	Venus			17	54	50	27	50	36
			W C		8	17	55	13	27	51	50
		13	W C		8	17	55	54	27	50	10
			Venus			17	56	50	27	47	39
		14	Venus			17	58	42	27	44	13
			W C		8	17	59	50	27	45	10
		15	W C		8	17	59	0	27	39	30
			Venus			18	0	26	27	40	21
		16	Venus			18	2	2	27	36	1
			W C		7	18	4	44	27	32	12
		17	Venus			18	3	29	27	31	13
			W C		7	18	4	44	27	32	12
		18	Venus			18	4	47	27	25	58
			W C		7	18	6	58	27	27	20
		19	Venus			18	5	55	27	20	15
			W C		10	18	7	0	27	15	50
		20	Venus			18	6	55	27	14	5
			W C		10	18	7	0	27	15	50
		21	Venus			18	7	44	27	7	28
			B A C	6194	5 6	18	8	40	27	5	30
		22	Venus			18	8	23	27	0	23
			B A C	6194	5 6	18	8	40	27	5	30
		23	Venus			18	8	54	26	52	51
			W C.		9	18	13	52	26	55	27

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			SOUTH DECLINATION		
					H.	M	S.	°	′	″
1850.	November 24	Venus			18	9	12	26	44	49
		W C.		5.6	18	18	9	26	44	1
	25	Venus			18	9	20	26	36	21
		W. C		8	18	15	20	26	34	0
	26	Venus			18	9	17	26	27	23
		Taylor	8458	8 9	18	12	44	26	29	23
	27	Venus			18	9	4	26	17	57
		W. C		7	18	10	5	26	22	40
	28	Venus			18	8	40	26	8	2
		B A C.	6214	7	18	11	54	26	8	28
	29	Venus			18	8	6	25	57	38
		W C.		8	18	9	23	25	54	0
	30	W C		8	18	6	40	25	45	10
		Venus			18	7	20	25	46	43
	December 1	Venus			18	6	24	25	35	19
		W. C.		8	18	7	2	25	35	40
	2	W C.		7	18	4	32	25	26	0
		Venus			18	5	17	25	23	25
	3	Venus			18	4	0	25	11	2
		W C		6	18	4	7	25	11	0
	4	W. C	(double)	8	17	58	12	25	7	0
		Venus			18	2	33	24	58	8
	5	W. C		7	17	59	4	24	44	0
		Venus			18	0	57	24	44	45
	6	H C	33084	8	17	55	58	24	24	2
		Venus			17	59	11	24	30	53
	7	H C	33113	8.9	17	56	54	24	12	7
		Venus			17	57	13	24	16	34
	8	Within 15° of the sun								
	24	Venus			17	15	12	19	30	10
		H C	31649	8	17	16	38	19	34	59
	25	Venus			17	13	27	19	16	50
		H C.	31564	8	17	14	25	19	17	59
	26	H C	31462	6 7	17	11	46	19	10	5
		Venus			17	11	51	19	4	13

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			SOUTH DECLINATION		
						H	M	S	°	′	″
1850	December	27	Venus			17	10	24	18	52	19
			H C.	31429	8	17	10	42	18	47	19
		28	Venus			17	9	6	18	41	12
			H C.	31429	8	17	10	42	18	47	19
		29	H C.	31258	9	17	3	40	18	21	21
			Venus			17	7	59	18	30	52
		30	H C.	31258	9	17	3	40	18	21	21
			Venus			17	7	2	18	21	21
		31	H C.	31225	8 9	17	2	48	18	8	57
			Venus			17	6	15	18	12	38
1851	January	1	H C	31225	8 9	17	2	48	18	8	57
			Venus			17	5	37	18	4	16
		2	Venus			17	5	10	17	57	46
			H C.	31354	9	17	7	58	17	57	57
		3	H C	31170	9	17	1	16	17	49	8
			Venus			17	4	53	17	51	31
		4	Venus			17	4	47	17	46	6
			H C	31356	8	17	8	0	17	44	23
		5	Venus			17	4	49	17	41	27
			H C.	31356	8	17	8	0	17	44	23
		6	Venus			17	5	2	17	37	33
			B. A C	5839	6 7	17	11	10	17	35	38
		7	Venus			17	5	24	17	34	23
			B. A C	5839	6.7	17	11	10	17	35	38
		8	Venus			17	5	56	17	31	55
			B A C	5839	6 7	17	11	10	17	35	38
		9	Venus			17	6	38	17	30	8
			B A C	5839	6 7	17	11	10	17	35	38
		10	Venus			17	7	26	17	29	0
			B A C	5839	6 7	17	11	10	17	35	38
		11	Venus			17	8	25	17	28	27
			B. A. C	5839	6.7	17	11	10	17	35	38
		12	Venus			17	9	32	17	28	30
			B A C	5839	6 7	17	11	10	17	35	38
		13	Venus			17	10	47	17	29	4
			B A C	5839	6 7	17	11	10	17	35	38

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			SOUTH DECLINATION		
						H	M	S	°	′	″
1851	January	14	B A C.	5839	6.7	17	11	10	17	35	38
			Venus			17	12	11	17	30	9
		15	Venus			17	13	42	17	31	42
			H C	31543	8	17	13	52	17	33	8
		16	H C	31543	8	17	13	52	17	33	8
			Venus			17	15	20	17	33	40
		17	H C	31543	8	17	13	52	17	33	8
			Venus			17	17	7	17	35	59
		18	Venus			17	19	0	17	38	46
			H C	31784	8 9	17	20	56	17	40	54
		19	Venus			17	21	0	17	41	50
			H C	31791	8	17	21	14	17	41	14
		20	Venus			17	23	7	17	45	8
			H C	31931	8	17	25	14	17	43	35
		21	H C	31931	8	17	25	14	17	43	35
			Venus			17	25	20	17	48	43
		22	H C	32010	7.8	17	27	29	17	45	26
			Venus			17	27	40	17	52	30
		23	H C	31954	7	17	25	47	18	6	47
			Venus			17	30	6	17	56	29
		24	Venus			17	37	37	18	0	36
			Taylor	8219	7 8	17	38	41	18	2	42
		25	Venus			17	35	14	18	4	50
			Taylor	8219	7 8	17	38	41	18	2	42
		26	Venus			17	37	56	18	9	4
			H C	32426	8	17	38	40	18	2	49
		27	Venus			17	40	44	18	13	30
			H C	32706	9 10	17	46	19	18	15	33
		28	Venus			17	43	36	18	17	54
			H C	32706	9 10	17	46	19	18	15	33
		29	H C	32706	9 10	17	46	19	18	15	33
			Venus			17	46	34	18	22	18
		30	Venus			17	49	36	18	26	39
			H C	32937	8	17	52	24	18	30	8
		31	H C	32937	8	17	52	24	18	30	8
			Venus			17	52	42	18	30	57

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852	May 29	Bessel	339	9	7	37	46	24	11	0
		Venus			7	39	26	24	17	56
	30	Bessel	339	8	7	42	29	24	6	16
		Venus			7	42	46	24	6	46
	31	Venus			7	46	0	23	55	17
		Bessel	339	8	7	47	17	24	0	40
	June 1	Venus			7	49	10	23	43	29
		H C	15548	7 8	7	50	53	23	35	0
	2	H C	15548	7 8	7	50	53	23	35	0
		Venus			7	52	15	23	31	25
	3	H C	15551	9	7	50	58	23	19	13
		Venus			7	55	16	23	19	6
	4	B A C	2700	6	7	57	32	23	3	15
		Venus			7	58	11	23	6	31
	5	Bessel	279	9	7	59	15	22	50	45
		Venus			8	1	1	22	53	44
	6	Venus			8	3	46	22	40	43
		H. C	16016	9 10	8	4	5	22	49	13
	7	Venus			8	6	26	22	27	31
		Bessel	278	9	8	6	55	22	19	6
	8	Bessel	278	9	8	6	55	22	19	6
		Venus			8	9	0	22	14	9
	9	H C	16236	8.9	8	10	15	21	57	10
		Venus			8	11	28	22	0	38
	10	Venus			8	13	50	21	46	59
		Bessel	278	9	8	15	14	21	51	16
	11	Venus			8	16	6	21	33	12
		H C	16582	7	8	19	29	21	38	29
	12	Venus			8	18	16	21	19	21
		H C	16659	9	8	21	44	21	21	3
	13	Venus			8	20	20	21	5	24
		H C	16677	9 10	8	22	21	21	8	36
	14	H C	16641	9	8	20	53	20	55	7
		Venus			8	22	17	20	51	25
	15	Venus			8	24	7	20	37	23
		H C	17013	8	8	31	11	20	36	20

DATE.		OBJECTS TO BE OBSERVED		MAG.	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852.	June 16	Venus			8	25	50	20	23	21
		H C	16851	8	8	27	14	20	16	48
	17	Bessel	277	9	8	24	44	20	8	57
		Venus			8	27	25	20	9	19
	18	Venus			8	28	54	19	55	19
		H C	16931	8 9	8	29	10	20	1	58
	19	H C	16940	6	8	29	17	19	46	52
		Venus			8	30	14	19	41	22
	20	Venus			8	31	27	19	27	29
		Rumker	2615	9	8	33	30	19	26	8
	21	Venus			8	32	32	19	13	42
		Bessel	277	7	8	37	4	19	21	6
	22	Bessel	274	9	8	32	34	19	0	45
		Venus			8	33	28	19	0	2
	23	Bessel	274	9	8	32	23	18	46	15
		Venus			8	34	16	18	46	31
	24	Venus			8	34	55	18	33	9
		Bessel	274	9	8	39	22	18	35	45
	25	Venus			8	35	25	18	19	59
		Bessel	274	8	8	39	57	18	11	51
	26	Venus			8	35	46	18	7	1
		Bessel	274	8	8	38	5	18	2	3
	27	Venus			8	35	57	17	54	16
		Bessel	274	9	8	39	42	17	56	11
	28	Venus			8	35	59	17	41	47
		Bessel	274	9	8	38	56	17	49	7
	29	H C	16974	8	8	30	6	17	34	33
		Venus			8	35	52	17	29	35
	30	Venus			8	35	35	17	17	39
		Rumker	2644		8	38	53	17	6	32
	July 1	Venus			8	35	8	17	6	2
		Rumker	2644		8	38	53	17	6	32
	2	Venus			8	34	31	16	54	43
		Bessel	273	9	8	36	7	16	56	21
	3	Rumker	2607	8	8	31	20	16	39	37
		Venus			8	33	44	16	43	50

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852.	July 4	Rumker	2607	8	8	31	20	16	39	37
		Venus			8	32	48	16	33	16
	5	Venus			8	31	42	16	23	5
		Bessel	273	9	8	33	54	16	15	31
	6	Bessel	273	9	8	27	55	16	13	37
		Venus			8	30	26	16	13	19
	7	Bessel	273	9	8	28	38	16	9	49
		Venus			8	29	2	16	3	57
	8	Bessel	273	9	8	23	20	15	53	43
		Venus			8	27	28	15	55	1
	9	Bessel	273	7.8	8	24	24	15	46	22
		Venus			8	25	45	15	46	31
	10	Bessel	273	8	8	19	39	15	35	2
		Venus			8	23	55	15	38	28
	11	Bessel	273	8	8	19	39	15	35	2
		Venus			8	21	56	15	30	53
	12	Bessel	273	9	8	18	30	15	24	36
		Venus			8	19	51	15	23	45
	13	Venus			8	17	37	15	17	6
		Bessel	273	8	8	18	39	15	18	18
	14	Venus			8	15	19	15	10	56
		Bessel	273	8.9	8	18	16	15	11	59
	15	Venus			8	12	55	15	5	11
		Bessel	273	9	8	13	37	15	4	41
	16	Within 15° of the sun								
	25	H. C.	15265	8.9	7	43	5	14	32	42
		Venus			7	44	41	14	33	52
	26	Venus			7	42	21	14	33	41
		H. C.	15265	8.9	7	43	5	14	32	42
	27	H. C.	15139	8.9	7	39	16	14	30	39
		Venus			7	40	7	14	33	53
	28	Venus			7	38	0	14	34	23
		H. C.	15139	8.9	7	39	16	14	30	39
	29	H. C.	14961	6.7	7	33	42	14	33	10
		Venus			7	36	1	14	35	25

DATE		OBJECTS TO BE OBSERVED		MAG.	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852	July 30	H. C	14961	6 7	7	33	42	14	33	10
		Venus			7	34	8	14	36	43
	31	H C.	14861	7	7	29	29	14	40	18
		Venus			7	32	25	14	38	19
	August 1	H C.	14861	7	7	29	29	14	40	18
		Venus			7	30	50	14	40	14
	2	Venus			7	29	25	14	42	25
		H C	14861	7	7	29	29	14	40	18
	3	Venus			7	28	9	14	44	51
		Bessel	273	8	7	30	57	14	47	48
	4	Venus			7	27	3	14	47	31
		Bessel	273	8	7	30	57	14	47	48
	5	H C.	14596	9	7	22	56	14	48	38
		Venus			7	27	3	14	50	24
	6	H C	14596	9	7	22	56	14	48	38
		Venus			7	25	21	14	53	27
	7	Venus			7	24	46	14	56	41
		Bessel	273	9 10	7	30	37	14	53	44
	8	Venus			7	24	19	15	0	2
		Bessel	273	9.10	7	30	37	14	53	44
	9	Venus			7	24	3	15	3	29
		Nearest *following* star								
	10	Venus			7	23	57	15	7	2
		Bessel	276	9	7	26	50	15	15	7
	11	Venus			7	24	0	15	10	38
		Bessel	276	9	7	26	50	15	15	7
	12	Venus			7	24	14	15	14	17
		Bessel	276	9	7	26	50	15	15	7
	13	Venus			7	24	36	15	17	56
		Bessel	276	9	7	26	50	15	15	7
	14	Venus			7	25	8	15	21	34
		Bessel	276	8 9	7	29	27	15	24	49
	15	Venus			7	25	48	15	25	11
		Bessel	276	8 9	7	29	27	15	24	49
	16	Venus			7	26	38	15	28	43
		Bessel	276	8.9	7	29	27	15	24	49

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
					H.	M	S.	°	′	″
1852.	August 17	Bessel	276	9	7	23	54	15	35	37
		Venus			7	27	35	15	32	11
	18	Bessel	276	9	7	23	54	15	35	37
		Venus			7	28	42	15	32	11
	19	Venus			7	29	56	15	38	47
		Bessel	273	9	7	31	30	15	40	20
	20	Venus			7	31	17	15	41	53
		Bessel	273	9	7	31	30	15	40	20
	21	Bessel	273	8	7	32	43	15	40	27
		Venus			7	32	47	15	44	49
	22	Bessel	273	9	7	33	48	15	49	57
		Venus			7	34	24	15	47	33
	23	Bessel	273	9	7	33	48	15	49	57
		Venus			7	36	8	15	50	0
	24	Venus			7	37	58	15	52	25
		H C	15125	9	7	38	58	15	53	10
	25	H C.	15125	9	7	38	58	15	53	10
		Venus			7	39	55	15	54	30
	26	H C.	15125	9	7	38	58	15	53	10
		Venus			7	42	1	15	56	20
	27	Venus			7	44	9	15	57	53
		H C	15338	9	7	44	53	15	58	50
	28	H C	15338	9	7	44	53	15	58	50
		Venus			7	46	25	15	59	18
	29	H C.	15338	9	7	44	53	15	58	50
		Venus			7	48	47	16	0	5
	30	Venus			7	51	14	16	0	43
		Bessel	273	9	7	53	31	15	58	6
	31	Bessel	273	9	7	53	31	15	58	6
		Venus			7	53	46	16	1	24
	September 1	Bessel	273	9	7	53	31	15	58	6
		Venus			7	56	24	16	0	57
	2	Bessel	273	9	7	53	31	15	58	6
		Venus			7	59	6	16	0	32
	3	Venus			8	1	54	15	59	44
		H C	16068	9	8	5	27	16	4	30

TABLE I —*Ephemeris for observing* VENUS *in* 1852

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852	September 4	Venus			8	4	45	15	58	34
		H C	16068	9	8	5	27	16	4	30
	5	Venus			8	7	41	15	57	0
		Bessel	273	9	8	11	51	15	55	51
	6	Venus			8	10	42	15	55	1
		Bessel	273	9	8	11	51	15	55	51
	7	Bessel	273	9	8	11	51	15	55	51
		Venus			8	13	46	15	53	42
	8	Bessel	273	8	8	15	1	15	44	36
		Venus			8	16	54	15	49	48
	9	Bessel	273	8	8	15	1	15	44	36
		Venus			8	20	6	15	46	33
	10	Venus			8	23	21	15	42	52
		Bessel	273	7 8	8	24	24	15	46	22
	11	Venus			8	26	39	15	38	43
		Bessel	273	8	8	29	46	15	39	0
	12	Bessel	273	9	8	29	41	15	32	40
		Venus			8	30	1	15	34	8
	13	Bessel	273	9	8	29	41	15	32	40
		Venus			8	33	25	15	29	6

TABLE II.

EPHEMERIS

OF

MARS AND ITS STARS OF COMPARISON,

DURING

THE OPPOSITION OF THE PLANET,

IN

1849 & 1852,

BY LIEUT J. M GILLISS, U S N

TABLE II —*Ephemeris for obseıvıng* Mars *ın* 1849

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
						H	M	S	°	′	″
1849	Novembeı	1	Bessel	348	9	6	18	48	24	20	52
			Mars			6	25	30	24	18	43
		2	Bessel	348	9	6	18	48	24	20	52
			Mars			6	25	52	24	21	9
		3	Mars			6	26	12	24	23	37
			Bessel	348	9	6	27	55	24	31	37
		4	Maıs			6	26	27	24	26	11
			Bessel	348	9	6	27	55	24	31	37
		5	Maıs			6	26	40	24	28	47
			Bessel	348	9	6	27	55	24	31	37
		6	Maıs			6	26	47	24	31	26
			Bessel	348	9	6	27	55	24	31	37
		7	Mars			6	26	52	24	34	10
			Bessel	348	7 8	6	29	6	24	35	6
		8	Mars			6	26	54	24	36	56
			Bessel	348	7 8	6	29	6	24	35	6
		9	Maıs			6	26	51	24	39	48
			B A C	2154	6 7	6	28	15	24	42	32
		10	Mars			6	26	45	24	42	44
			B A C	2154	6 7	6	28	15	24	42	32
		11	Maıs			6	26	35	24	45	13
			B A C	2154	6 7	6	28	15	24	42	32
		12	H C	12557	9	6	25	51	24	44	12
			Mars			6	26	21	24	48	47
		13	H C	12557	9	6	25	51	24	44	42
			Mars			6	26	3	24	51	53
		14	Maıs			6	25	41	24	55	2
			Bessel	348	9	6	28	47 5	24	58	22
		15	Mars			6	25	16	24	58	15
			Bessel	348	9	6	28	47 5	25	58	22
		16	Mars			6	24	46	25	1	31
			H C.	12554	8	6	25	48	25	2	4
		17	Mars			6	24	13	25	4	48
			H C	12558	9	6	25	48	25	2	4
		18	Bessel	348	9	6	19	54	25	9	35
			Mars			6	23	36	25	7	9

Date			Objects to be observed		Mag	Right Ascension			North Declination		
						H	M	S	°	′	″
1849	November	19	Bessel	348	9	6	19	54	25	9	35
			Mars			6	22	55	25	11	34
		20	Bessel	523	9	6	21	15	25	13	36
			Mars			6	22	11	25	14	54
		21	Bessel	523	9	6	21	15	25	13	36
			Mars			6	21	22	25	18	19
		22	Mars			6	20	30	25	21	45
			Bessel	523	9	6	24	2	25	22	24
		23	Bessel	523	9	6	18	9	25	26	47
			Mars			6	19	34	25	25	10
		24	Mars			6	18	35	25	28	36
			Bessel	523	9	6	21	45	25	30	43
		25	Mars			6	17	32	25	32	1
			Bessel	523	9	6	21	45	25	30	43
		26	Mars			6	16	25	25	35	25
			H C	12237	9	6	16	51	25	35	35
		27	Mars			6	15	16	25	38	47
			H C	12240	8	6	16	58	25	40	39
		28	Mars			6	14	2	25	42	8
			H C.	12240	8	6	16	58	25	40	39
		29	H C	12041	8	6	11	18	25	40	19
			Mars			6	12	45	25	45	25
		30	Mars			6	11	26	25	48	40
			Bessel	405	9	6	11	37	25	45	34
	December	1	Mars			6	10	4	25	51	51
			H C	11996	9	6	10	8	25	44	21
		2	Mars			6	8	39	25	54	37
			Bessel	523	9	6	9	2	25	56	35
		3	Mars			6	7	11	25	58	0
			Bessel	523	9	6	9	2	25	56	35
		4	H C.	11714	9	6	2	26	26	0	48
			Mars			6	5	41	26	0	56
		5	H C	11714	9	6	2	26	26	0	48
			Mars			6	4	8	26	3	47

* Double. Observe south preceding star.

TABLE II.—*Ephemeris for observing* Mars *in* 1849

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
						H	M	S	°	′	″
1849	December	6	H C	11714	9	6	2	26	26	0	48
			Mars			6	2	33	26	6	31
		7	Mars			6	0	56	26	9	9
			Bessel	405	8 9	6	1	34	26	2	19
		8	Rumker	1701		5	57	14	26	20	11
			Mars			5	59	18	26	11	39
		9	Rumker	1701		5	57	14	26	20	11
			Mars			5	57	37	26	14	1
		10	Rumker	1673		5	54	7	26	16	32
			Mars			5	55	56	26	16	25
		11	Rumker	1673		5	54	7	26	16	32
			Mars			5	45	13	26	18	20
		12	Mars			5	52	28	26	20	17
			Rumker	1680	8	5	54	32	26	21	1
		13	Mars			5	50	44	26	22	5
			Rumker	1680	8	5	54	32	26	21	1
		14	Bessel	405	9	5	46	16	26	27	17
			Mars			5	48	59	26	23	43
		15	Bessel	405	9	5	46	16	26	27	17
			Mars			5	47	13	26	25	12
		16	Mars			5	45	28	26	26	32
			Bessel	405	9	5	46	16	26	27	17
		17	Mars			5	43	42	26	27	42
			Bessel	405	9	5	46	16	26	27	17
		18	Mars			5	41	57	26	28	43
			Bessel	405	9	5	46	16	26	27	17
		19	Mars			5	40	13	26	29	34
			Bessel	405	9	5	46	16	26	27	17
		20	Bessel	405	7	5	29	34	26	32	4
			Mars			5	38	30	26	30	17
		21	Bessel	405	7	5	29	34	26	32	4
			Mars			5	36	48	26	30	50
		22	Bessel	405	7	5	29	34	26	32	4
			Mars			5	35	7	26	31	14
		23	Bessel	405	7	5	29	34	26	32	4
			Mars			5	33	27	26	31	30

DATE		OBJECTS TO BE OBSERVED		MAG.	RIGHT ASCENSION			NORTH DECLINATION		
					H.	M.	S.	°	′	″
1849.	December 24	Bessel	405	7	5	29	34	26	32	4
		Mars			5	31	50	26	31	38
	25	Bessel	405	7	5	29	34	26	32	4
		Mars			5	30	14	26	31	38
	26	Mars			5	28	51	26	31	30
		Bessel	405	7	5	29	34	26	32	4
	27	Mars			5	27	9	26	31	15
		Bessel	405	7	5	29	34	26	32	4
	28	Bessel	405	8	5	25	33	26	32	44
		Mars			5	25	40	26	30	55
	29	Mars			5	24	14	26	30	29
		Bessel	405	8	5	25	33	26	32	44
	30	Bessel	405	9	5	21	41	26	28	18
		Mars			5	22	50	26	29	56
	31	Mars			5	21	29	26	29	18
		Bessel	405	9	5	21	38	26	28	17
1850.	January 1	Mars			5	20	11	26	28	36
		Bessel	405	9	5	21	38	26	28	17
	2	Mars			5	18	56	26	27	50
		Bessel	405	9	5	24	38	26	28	17
	3	Bessel	523	8.9	5	17	42	26	27	19
		Mars			5	17	44	26	27	0
	4	Mars			5	16	36	26	26	5
		Bessel	523	8.9	5	17	42	26	27	19
	5	Mars			5	15	30	26	25	9
		Bessel	523	8.9	5	17	42	26	27	19
	6	Mars			5	14	28	26	24	10
		Bessel	523	8.9	5	17	42	26	27	19
	7	Mars			5	13	30	26	23	9
		Bessel	523	8.9	5	17	42	26	27	19
	8	Mars			5	12	35	26	22	7
		Bessel	523	8.9	5	17	42	26	27	19
	9	Mars			5	11	43	26	21	3
		Bessel	523	8.9	5	17	42	26	27	19
	10	Bessel	396	8	5	3	3	26	16	33
		Mars			5	10	55	26	19	59

TABLE II.—*Ephemeris for observing* MARS *in* 1850.

DATE.		OBJECTS TO BE OBSERVED.		MAG.	RIGHT ASCENSION.			NORTH DECLINATION		
					H.	M.	S.	°	′	″
1850.	January 11	Bessel Mars	396	8	5 5	3 10	3 11	26 26	16 18	33 54
	12	Bessel Mars	396	8	5 5	3 9	3 30	26 26	16 17	33 50
	13	Bessel Mars	396	8	5 5	3 8	3 53	26 26	16 16	33 47
	14	Bessel Mars	396	8	5 5	3 8	3 20	26 26	16 15	33 44
	15	Bessel Mars	396	8	5 5	3 7	3 50	26 26	16 14	33 42
	16	Bessel Mars	396	8	5 5	3 7	3 24	26 26	16 13	33 41
	17	Bessel Mars	396	8	5 5	3 7	3 1	26 26	16 12	33 43
	18	Bessel Mars	396	8	5 5	3 6	3 42	26 26	16 11	33 46
	19	Mars Bessel	405	9	5 5	6 10	27 45	26 26	10 5	52 56
	20	Mars Bessel	405	9	5 5	6 10	15 45	26 26	10 5	0 56
	21	Mars Bessel	405	9	5 5	6 10	7 45	26 26	9 5	10 56
	22	Mars Bessel	405	9	5 5	6 10	2 45	26 26	8 5	22 56
	23	Mars Bessel	405	9	5 5	6 10	1 45	26 26	7 5	37 56
	24	Mars Bessel	405	9	5 5	6 10	4 45	26 26	6 5	55 56
	25	Mars Bessel	405	9	5 5	6 10	9 45	26 26	6 5	16 56
	26	Mars Bessel	405	9	5 5	6 10	17 45	26 26	5 5	41 56
	27	Mars Bessel	405	9	5 5	6 10	29 45	26 26	5 5	6 56
	28	Mars Bessel	405	9	5 5	6 10	44 45	26 26	4 5	34 56

DATE		OBJECTS TO BE OBSERVED		MAG.	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1850	January 29	Mars			5	7	3	26	1	6
		Bessel	405	9	5	10	15	26	5	56
	30	Mars			5	7	21	26	3	10
		Bessel	405	9	5	10	45	26	5	56
	31	Mars			5	7	48	26	3	16
		Bessel	405	9	5	10	45	26	5	56

DATE.		OBJECTS TO BE OBSERVED.		MAG.	RIGHT ASCENSION.			NORTH DECLINATION.		
					H.	M.	S.	°	′	″
1851.	December 15	Mars			9	9	30	19	42	1
		B. A. C.	3181	7.8	9	12	18	19	42	47
	16	Mars			9	9	30	19	41	49
		B. A. C.	3181	7.8	9	12	18	19	42	47
	17	Mars			9	9	26	19	47	51
		B. A. C.	3181	7.8	9	12	18	19	42	47
	18	Bessel	275	9	9	8	14	19	52	7
		Mars			9	9	18	19	51	8
	19	Bessel	275	9	9	8	14	19	52	7
		Mars			9	9	8	19	54	38
	20	Mars			9	8	54	19	58	23
		Bessel	275	9	9	10	22	20	2	34
	21	Mars			9	8	36	20	2	22
		Bessel	275	9	9	10	22	20	2	34
	22	Mars			9	8	15	20	6	35
		Washington		8	9	10	22	20	3	35
	23	Washington		9	9	6	0	20	8	48
		Mars			9	7	51	20	11	2
	24	Mars			9	7	24	20	15	42
		Washington		8	9	8	15	20	16	54
	25	Mars			9	6	53	20	20	35
		H. C.	18247	9	9	7	40	20	21	20
	26	Mars			9	6	18	20	25	41
		Rumker	2800		9	7	42	20	27	48
	27	Mars			9	5	40	20	31	0
		Rumker	2800		9	7	42	20	27	48
	28	Bessel	275	9	9	4	26	20	38	39
		Mars			9	4	59	20	36	30
	29	Mars			9	4	15	20	42	13
		Rumker	2799		9	7	40	20	41	9
	30	Mars			9	3	27	20	48	6
		Rumker	2799		9	7	40	20	41	9
	31	Mars			9	2	36	20	54	10
		Bessel	277	8.9	9	3	19	20	58	50
1852.	January 1	Mars			9	1	41	21	0	24
		Bessel	277	8.9	9	3	19	21	3	18

DATE.			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
						H	M	S	°	′	″
1852.	January	2	Bessel	275	8	8	58	15	21	8	10
			Mars			9	0	44	21	6	47
		3	Bessel	275	9	8	58	36	21	13	11
			Mars			8	59	43	21	13	19
		4	Mars			8	58	39	21	19	58
			H C.	18132	8 9	9	4	6	21	17	9
		5	Mars			8	57	32	21	26	45
			Bessel	278	9	8	59	28	21	28	49
		6	Bessel	278	9	8	53	47	21	33	45
			Mars			8	56	22	21	33	39
		7	Bessel	278	7 8	8	50	26	21	41	4
			Mars			8	55	10	21	40	38
		8	Bessel	278	7 8	8	50	26	21	41	1
			Mars			8	53	54	21	47	42
		9	Bessel	278	8	8	18	54	21	51	59
			Mars			8	52	36	21	54	50
		10	Mars			8	51	15	22	2	1
			Bessel	278	8	8	52	12	22	2	19
		11	Bessel	278	9	8	47	33	22	9	6
			Mars			8	49	52	22	9	14
		12	Bessel	278	8	8	17	26	22	15	43
			Mars			8	48	26	22	16	28
		13	Bessel	278	8	8	45	57	22	23	23
			Mars			8	46	58	22	23	43
		14	Bessel	278	9	8	44	14	22	34	36
			Mars			8	45	28	22	30	57
		15	Mars			8	43	57	22	38	9
			H C.	17583	9.10	8	47	26	22	38	15
		16	Bessel	344	9	8	40	25	22	45	41
			Mars			8	42	23	22	45	18
		17	Mars			8	40	48	22	52	24
			H C.	17513	9	8	45	28	22	51	46
		18	Mars			8	39	11	22	58	55
			Bessel	278	9	8	43	58	22	56	37
		19	Washington		9	8	34	44	23	5	21
			Mars			8	37	33	23	6	20

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852	January 20	Bessel	344	9	8	35	8	23	13	39
		Mars			8	35	55	23	13	8
	21	Washington		10	8	34	12	23	17	23
		Mars			8	34	15	23	19	50
	22	Washington		8	8	30	13	23	26	13
		Mars			8	32	35	23	26	23
	23	Washington		8	8	28	6	23	36	7
		Mars			8	30	51	23	32	17
	24	Bessel	344	9	8	28	15	23	15	30
		Mars			8	29	13	23	39	11
	25	Mars			8	27	33	23	15	1
		Bessel	344	9	8	28	15	23	15	30
	26	Mars			8	25	52	23	50	56
		Washington		9	8	26	27	23	52	36
	27	Mars			8	21	12	23	56	36
		Washington		9	8	26	39	23	56	36
	28	H C.	16464	9	8	16	38	21	1	10
		Mars			8	22	32	21	2	3
	29	Washington			8	20	0	21	8	2
		Mars			8	20	53	21	7	18
	30	Mars			8	19	16	21	12	19
		Washington			8	19	30	21	10	12
	31	Mars			8	17	39	21	17	7
		Washington			8	20	3	21	16	25
	February 1	Mars			8	16	4	21	21	10
		Bessel	344	8	8	16	7	21	25*	50
	2	Mars			8	14	31	21	25	59
		Bessel	344	8	8	16	7	21	25	50
	3	Mars			8	12	59	21	30	1
		Washington		9	8	13	7	21	29	39
	4	Mars			8	11	29	24	33	51
		H C	16337	10	8	13	17	21	33	51
	5	Mars			8	10	1	21	37	29
		H C.	16237	7	8	10	11	24	38	3
	6	Mars			8	8	35	21	10	50
		H C	16237	7	8	10	11	21	38	3

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
						H	M	S.	°	′	″
1852	February	7	Bessel	341	9	8	6	19	24	45	40
			Mars			8	7	11	24	43	56
		8	Mars			8	5	50	24	46	47
			Bessel	341	9	8	6	19	24	45	40
		9	Mars			8	4	32	24	49	24
			Bessel	341	9	8	6	19	24	45	37
		10	Bessel	341	9	7	59	27	24	51	22
			Mars			8	3	16	24	51	46
		11	Bessel	341	9	7	59	27	24	51	22
			Mars			8	2	3	24	53	54
		12	Bessel	341	9	7	59	27	24	51	22
			Mars			8	0	55	24	55	47
		13	Bessel	341	9	7	55	17	24	51	0
			Mars			7	59	45	24	57	27
		14	Bessel	341	9	7	55	5	24	59	16
			Mars			7	58	41	24	58	53
		15	Bessel	341	9	7	55	5	24	59	16
			Mars			7	57	40	25	0	5
		16	Bessel	341	9	7	55	5	24	59	16
			Mars			7	56	42	25	1	4
		17	Bessel	341	9	7	55	5	24	59	16
			Mars			7	55	47	25	1	50
		18	Mars			7	54	56	25	2	24
			Bessel	341	9	7	55	5	24	59	16
		19	Mars			7	54	8	25	2	45
			Bessel	341	9	7	55	5	24	59	16
		20	Mars			7	53	23	25	2	54
			Bessel	341	9	7	55	5	24	59	16
		21	Mars			7	52	42	25	2	52
			Bessel	341	9	7	55	5	24	59	16
		22	Mars			7	52	4	25	2	38
			Bessel	341	9	7	55	5	24	59	16
		23	Mars			7	51	29	25	2	13
			Bessel	341	9	7	55	5	24	59	16
		24	Mars			7	50	58	25	1	37
			Bessel	341	9	7	55	5	24	59	16

DATE			OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
						H	M	S	°	′	″
1852	February	25	Bessel	341	8	7	47	8	25	2	0
			Mars			7	50	30	25	0	51
		26	Bessel	341	8	7	47	8	25	2	0
			Mars			7	50	6	24	59	51
		27	Bessel	341	8	7	47	8	25	2	0
			Mars			7	49	46	24	58	17
		28	Bessel	341	9	7	48	41	24	52	53
			Mars			7	49	28	24	57	31
		29	Bessel	341	9	7	48	41	24	52	53
			Mars			7	49	14	24	56	6
	March	1	Bessel	341	9	7	48	41	24	52	53
			Mars			7	49	3	24	54	31
		2	Bessel	341	9	7	48	41	24	52	53
			Mars			7	48	56	24	52	18
		3	Bessel	341	9	7	48	41	24	52	53
			Mars			7	48	51	24	50	56
		4	H. C.	15401	8.9	7	46	38	24	44	56
			Mars			7	48	50	24	48	56
		5	H. C.	15401	8.9	7	46	38	24	44	56
			Mars			7	48	52	24	46	18
		6	H. C.	15401	8.9	7	46	38	24	44	56
			Mars			7	48	57	24	44	31
		7	H. C.	15412	9	7	46	53	24	37	50
			Mars			7	49	6	24	42	7
		8	H. C.	15412	9	7	46	53	24	37	50
			Mars			7	49	17	24	39	36
		9	H. C.	15412	9	7	46	53	24	37	50
			Mars			7	49	31	24	36	57
		10	H. C.	15412	9	7	46	53	24	37	50
			Mars			7	49	48	24	34	11
		11	Mars			7	50	8	24	31	17
			Bessel	339	9	7	50	58	24	29	10
		12	Mars			7	50	30	24	28	17
			Bessel	339	9	7	50	58	24	29	10
		13	Mars			7	50	56	24	25	9
			Bessel	339	9	7	50	58	24	29	10

DATE		OBJECTS TO BE OBSERVED		MAG	RIGHT ASCENSION			NORTH DECLINATION		
					H	M	S	°	′	″
1852	March 14	Mars			7	51	24	24	21	55
		H C	15608	8	7	52	38	24	19	7
	15	Mars			7	51	55	24	18	34
		H C	15608	8	7	52	38	24	19	7

ОПРЕДѢЛЕНІЕ РАЗНОСТИ ДОЛГОТЪ НИКОЛАЕВА И БАТУМА

въ 1884 году.

Лѣтомъ 1884 года, по предложенію начальника военно-топографическаго отдѣла на Кавказѣ генералъ-маіора Стебницкаго, сдѣлано было опредѣленіе долготы Батума относительно Николаева помощью телеграфа. Работа эта была исполнена помощникомъ генералъ-маіора Стебницкаго генеральнаго штаба полковникомъ Кульбергомъ и астрономомъ морской обсерваторіи въ Николаевѣ Кортацци. По программѣ, заранѣе составленной обоими наблюдателями, опредѣленіе должно было основываться на наблюденіяхъ 12-ти вечеровъ, съ двукратною перемѣною мѣстъ наблюдателей Поправка хронометровъ опредѣлялась переносными пассажными инструментами, работы механика Гербста въ Пулковѣ, почти одинаковаго устройства, по способу В К Деллена въ вертикалѣ полярной звѣзды; при этомъ каждый наблюдатель, при благопріятной погодѣ, долженъ былъ каждый вечеръ сдѣлать два опредѣленія времени, располагая ихъ, по возможности, такъ, чтобы сравненія хронометровъ обоихъ наблюдателей заключались между ними.

Сравненія эти дѣлались посредствомъ сигналовъ, передаваемыхъ извѣстнымъ способомъ по телеграфу между обѣими станціями, приблизительно всегда въ одно и то же время. По ходатайству генералъ-маіора Стебницкаго директоръ телеграфнаго департамента предоставилъ наблюдателямъ право безплатнаго пользованія телеграфною линіею, для подачи сигналовъ ежедневно, на все время работы отъ 10 до 11 часовъ вечера по Петербургскому времени. Впрочемъ, въ случаяхъ, когда телеграфное сообщеніе было не совсѣмъ исправно, г г. начальники

телеграфныхъ станцій не препятствовали наблюдателямъ пользоваться линіею и нѣсколько позже опредѣленнаго времени. Вообще необходимо замѣтить, что всѣ чины телеграфнаго вѣдомства весьма заботливо относились къ производившейся работѣ, и употребляли всѣ мѣры къ успѣшному ея выполненію

Разстояніе между обоими пунктами, по линіи проводовъ, идущей отъ Николаева черезъ Симферополь, Керчь, Екатеринодаръ, Георгіевскъ, Тифлисъ, Кутаисъ, Батумъ, составляю около 1600 верстъ. Убѣдившись въ началѣ работы, что батареи въ 100—120 элементовъ, установленныя на обоихъ конечныхъ пунктахъ, недостаточны для прямаго дѣйствія, рѣшено было устроить трансляцію въ Екатеринодарѣ, которою затѣмъ и пользовались постоянно. Это обстоятельство, конечно, должно было увеличить, такъ называемое, *замедленіе тока* при передачѣ сигналовъ, но, какъ увидимъ ниже, постоянство этого замедленія даетъ поводъ надѣяться, что точность опредѣленной долготы отъ этого не уменьшилась Для исключенія постоянной ошибки, возможной вслѣдствіе неодинаковаго замедленія тока въ обоихъ реле, по которымъ принимались сигналы, каждый наблюдатель перевозилъ свое реле съ собою.

Въ Николаевѣ наблюденія производились въ малой вращающейся башнѣ обсерваторіи, въ Батумѣ—на кирпичномъ столбѣ, построенномъ полковникомъ Кульбергомъ на приморскомъ бульварѣ, вблизи дома, въ которомъ имъ была устроена временная телеграфная станція Столбъ этотъ связанъ тригонометрически полковникомъ Кульбергомъ съ Батумскимъ маякомъ и съ мечетью Азизіе.

Наблюденія были начаты $\frac{21\ \text{іюля}}{1\ \text{авг}}$ и окончены $\frac{4}{16}$ сентября, такъ что продолжались всего полтора мѣсяца, изъ коихъ 2 недѣли были употреблены на два переѣзда наблюдателей, собственно же для полученія 12-ти опредѣленій потребовалось 32 дня Это замедленіе произошло главнымъ образомъ вслѣдствіе чрезвычайно дождливой погоды въ Батумѣ, частью же вслѣдствіе поврежденій телеграфа Для полученія каждаго опредѣленія требовалась ясная погода въ обоихъ пунктахъ и исправное состояніе линіи, и, при столь значительномъ разстояніи между пунктами, эти три условія рѣдко совпадали. Извѣстно, что

въ сырую погоду изоляція проводовъ становится такъ слаба, что затрудняетъ дѣйствіе телеграфа даже на близкихъ разстояніяхъ, при протяженіи же проводовъ на 1 600 верстъ, особенно на Кавказѣ, гдѣ линія проходитъ во многихъ мѣстахъ по гористой и лѣсистой мѣстности, очень часто случалось, что вслѣдствіе сырой погоды, на томъ или другомъ участкѣ линіи, передача сигналовъ дѣлалась очень затруднительною, а иногда и вовсе невозможною. Такимъ образомъ, изъ 32-хъ вечеровъ, 8 было потеряно вслѣдствіе прекращенія телеграфнаго сообщенія, затѣмъ 2—по случаю болѣзни одного изъ наблюдателей, и наконецъ остальные вслѣдствіе пасмурности

Не смотря на значительное разстояніе между обоими пунктами, разность между двумя сравненіями хронометровъ, въ одинъ и тотъ же вечеръ, по сигналамъ поданнымъ въ ту и другую сторону, т. е удвоенное замедленіе тока сохранялось въ среднемъ чрезвычайно постояннымъ, именно эти разности получились слѣдующія

		с			с			с.
Авг	4. .	0,20	Авг	16.	0,24	Сент.	6. . .	0,22
	5 . .	,23		17. . .	,24		7.	,19
	6.	,24		18. . .	,24		8 .	,28
	Среднее	0,22		21 .	,25		10. .	,12
				22. . .	,23		11. . .	,20
				23. . .	,18		12. . .	,30
				24 . .	,17		13. . .	,23
				25 .	,21		16. . .	,26
				Средн .	0,22		Средн. .	0,22.

Любопытно при этомъ замѣтить, что наименьшая разность 0,12 получилась 10 сентября, именно въ тотъ вечеръ, когда въ журналѣ наблюденій находится замѣчаніе, что въ этотъ вечеръ телеграфъ дѣйствовалъ особенно хорошо.

Называя разность долготъ Батумъ—Николаевъ черезъ L, и личное уравненіе наблюдателей черезъ α, получаются два ряда опредѣленій, помѣщенные въ прилагаемомъ за симъ спискѣ. Въ столбцѣ p этого списка показаны вѣса, приданные этимъ опредѣленіямъ, при оцѣнкѣ коихъ наблюдатели руководства-

лись числомъ наблюденій полученныхъ въ данный вечеръ и качествомъ ихъ, согласно замѣчаніямъ, сдѣланнымъ ими въ наблюдательныхъ журналахъ. На этомъ основаніи результатамъ полученнымъ августа 23, 25 и сентября 11, данъ половинный вѣсъ, такъ какъ въ эти вечера, при передачѣ сигналовъ, Николаевскій токъ доходилъ въ Батумъ очень слабо и былъ непостояненъ, кромѣ того половинный вѣсъ приданъ выводу 24-го августа, вслѣдствіе очень ограниченнаго числа наблюденій звѣздъ, полученныхъ въ этотъ вечеръ на обѣихъ станціяхъ.

Число		$L+\alpha$	$L-\alpha$	p
		м с	с	
Августа	4	+38 36,63		1
	5	36,67		1
	6	36,76		1
	16		36,10	1
	17		36,12	1
	22		36,10	1
	23		35,96	1/2
	24		36,01	1/2
	25		36,03	1/2
Сентябр	6	36,71		1
	11	36,73		1/2
	16	36,60		1

Принимая въ расчетъ вѣса опредѣленій, получаемъ слѣдующія среднія

$$\begin{array}{rl} & \text{ч}\quad\text{м}\quad\text{с} \\ L+\alpha= & 0\ 38\ 36{,}679 \\ L-\alpha= & 36{,}071, \\ \hline L\ = & 0\ 38\ 36{,}375, \end{array}$$

откуда $L=0\ 38\ 36{,}375$, а личное уравненіе Кульберга отн Кортацци $\alpha=+0{,}304$, величина весьма близко подходящая къ личному уравненію Кульберга относительно другихъ наблюдателей, выведенному при опредѣленіи разности долготъ въ Сибири въ 1873—1876 годахъ вмѣстѣ съ полковникомъ Шарнгорстомъ, и въ 1883 году при опредѣленіи долготъ на Кавказѣ съ полковникомъ Гладышевымъ

Именно Кульбергъ относительно Шарнгорста $=+0{,}265$

— — — Гладышева $=+0{,}250$.

Столбъ, на которомъ производились наблюденія въ Батумѣ, по опредѣленію г. Кульберга, отстоитъ

на 1,572 с къ W отъ мечети Азизіе, и

на 1,633 с — — — маяка;

въ Николаевѣ же малая вращающаяся башня находится на 0,115 с. къ Осту отъ центра обсерваторіи Такимъ образомъ долгота маяка въ Батумѣ отъ центра обсерваторіи въ Николаевѣ=0 ч 38 м 36,375 с +1,748 с.=0 ч. 38 м 38,12 с, съ вѣроятною ошибкою±0,012 с

Долгота эта еще не можетъ считаться окончательною, такъ какъ другія служебныя занятія до настоящаго времени не дали возможности полковнику Кульбергу закончить предположенную программу опредѣленій непосредственною связью по долготѣ Батума съ Тифлисомъ, разность долготъ которыхъ основывается пока на связи черезъ Николаевъ, Кіевъ и Ростовъ. Прямая же связь этихъ двухъ пунктовъ представитъ данныя, которыя послужатъ какъ для окончательнаго вывода долготъ всѣхъ промежуточныхъ пунктовъ, такъ и для оцѣнки точности произведенныхъ операцій. Затѣмъ желательно также, пользуясь орографическими данными въ окрестностяхъ Батума, вычислить ожидаемое тамъ отклоненіе отвѣсной линіи.

Астрономъ Н. Кортацци.

(Изъ № 9 «Морскаго Сборника» 1885 г).

PAPERS

RELATING TO

THE TRANSIT OF VENUS IN 1874,

PREPARED UNDER THE DIRECTION OF

THE COMMISSION AUTHORIZED BY CONGRESS

AND PUBLISHED

BY AUTHORITY OF THE HON. SECRETARY OF THE NAVY.

PART I.

WASHINGTON:
GOVERNMENT PRINTING OFFICE
1872

TABLE OF CONTENTS.

INTRODUCTORY NOTE.

A Commission to expend such appropriations as might be made by Congress for the observations of the coming transit of Venus was formed by section 2 of the naval appropriation bill approved March 4, 1871. It consists of the following members:

Rear-Admiral B. F. SANDS, Superintendent U. S. Naval Observatory.
Professor JOSEPH HENRY, LL.D., President National Academy of Sciences.
Professor BENJAMIN PEIRCE, LL.D., Superintendent U. S. Coast Survey.
Professor SIMON NEWCOMB, U. S. Navy, Naval Observatory.
Professor WM. HARKNESS, U. S. Navy, Naval Observatory.

At a meeting of this Commission held at the United States Naval Observatory, Washington, D. C., on July 24, 1872, it was resolved to print such papers relating to the subject as might be of sufficient interest and importance. The following selection has been made in pursuance of this action.

PAPERS

RELATING TO

THE TRANSIT OF VENUS IN DECEMBER 1874.

I

Letter of Rear-Admiral Sands to the Secretary of the Navy, suggesting the advisability of asking Congress to appropriate the necessary funds for fitting out expeditions to observe the transit of Venus in December, 1874

UNITED STATES NAVAL OBSERVATORY,
Washington City, March 5, 1872

SIR I have the honor to call your attention to the advisability of making national provision for the observation of one of the rarest and most interesting phenomena in astronomy, a transit of Venus across the disk of the sun Such a transit will occur on December 8, 1874, and again in the year 1882, after which there will be none until the year 2004 The astronomers of Great Britain, Prussia, and Russia, aided by liberal grants of money from their respective governments, have been engaged for more than a year in active preparation for the observation of the first, while in this country very little has been done

Such a phenomenon will afford our countrymen a peculiarly favorable opportunity to exercise their inventive ingenuity in the introduction of improved modes of observation Their successful introduction of two of the most important appliances in practical astronomy—astronomical photography and the electro-chronograph, both of which are now widely adopted in Europe,—their successful competition with Europeans in producing some of the finest classes of astronomical instruments, and the rapid advances which practical astronomy has made in this country within the last few years, all warrant the belief that they can take a leading position in making the observations in question

In addition to the solution of one of the most important problems in astronomy, the proposed expedition will render important service to geography and navigation by the determination of the accurate position of numerous points in the Pacific Ocean

Congress at its last session, in making a small appropriation of $2,000 for experimenting upon the best form of instruments to be used, provided that any moneys which might hereafter be appropriated for the purpose in question, should be expended, with the approval of the Secretary of the Navy, under the direction of a Commission composed of the Superintendent and two Professors of Mathematics of the Naval Observatory, the President of the National Academy of Sciences, and the Superintendent of the Coast Survey

At a late meeting of the Commission the total cost of such expeditions as it was fitting the position of our country to undertake was estimated at $150,000, to be expended in three annual installments of $50,000. The first installment, that for the coming fiscal year, would be almost entirely spent in construction of instruments, the largest part of which will, it is probable, be of American manufacture. I therefore respectfully recommend that an appropriation of $50,000 for the construction of instruments for the observation of the transit of Venus be made by Congress at its present session.

Very respectfully, your obedient servant,

B. F. SANDS,
Rear-Admiral, Superintendent.

Hon. GEO. M. ROBESON,
Secretary of the Navy.

[Indorsement.]

NAVY DEPARTMENT,
Washington City, March 7, 1872.

The object of the within paper commends itself to men of science of all nations. In forwarding it the Department feels assured that it will receive the consideration due this interesting and useful subject, which at this time is being discussed by learned societies, while preparations are in progress for making the desired observations.

Respectfully,

GEO. M. ROBESON,
Secretary of the Navy.

To the CHAIRMEN OF THE COMMITTEES ON
APPROPRIATIONS, HOUSE AND SENATE.

II.

Letter of Rear-Admiral Sands to Mr. Rutherfurd, asking his views as to the best method of making photographic observations of the transit of Venus.

UNITED STATES NAVAL OBSERVATORY,
Washington City, D. C., January 19, 1872.

DEAR SIR: A Commission for the expenditure of any appropriation that might be made for observing the transit of Venus was designated by Congress, at its last session, in the naval appropriation bill approved March 3, 1871. This Commission, composed of the Superintendent and two Professors of Mathematics of the Naval Observatory, the President of the National Academy of Sciences, and the Superintendent of the Coast Survey, has instructed me, on its behalf, to ask your advice respecting the best method of applying photography to the determination of the relative positions of Venus and the sun during the transit.

It may not be amiss to mention some of the conditions which it is desirable that the apparatus should fulfill, though most of them may be familiar to you They appear to be

1 To secure an image of the sun at the photographic plate, which shall be free from all systematic distortion except such as can be accurately determined and allowed for

2 To secure an equal exposure of every part of the image on the plate

3 To have the means of determining with indisputable certainty the angular value of a given length, say one centimeter, on the plate Or, if this is impracticable, to avoid all errors except such minute ones as are common to all the instruments

4 To have the means of determining the angle of position as well as the distance of the centers of the bodies

I would be obliged for the communication of any other considerations that may occur to you

We are desirous of trying all the forms of photographic apparatus that may be suggested during the coming spring and summer, and especially of putting into operation any system you may suggest, leaving all the details to yourself so far as it may be practicable for you to carry them out If your health and engagements admit of your superintending the construction of such apparatus as you deem best adapted to the required purpose, we will be ready to pay the cost out of any appropriation that Congress may make for observing the transit

Very respectfully and truly, yours,

B F SANDS, *Rear-Admiral,*
Superintendent U S Naval Observatory

LEWIS M RUTHERFURD, Esq,
175 *Second Avenue, New York*

III

Letter of Mr Rutherfurd to Rear-Admiral Sands, giving a detailed description of the method of solar photography employed in his Observatory

175 SECOND AVENUE, NEW YORK,
January 23, 1872

DEAR SIR I think I can best reply to your letter of the 19th instant, making inquiries as to the application of photography to the coming transit of Venus, by describing the methods now, and for the last three years, in use in my observatory for photographing the sun, with results which I have not seen equaled by any other process

OBJECTIVE

The objective is corrected for photographic rays without reference to the effect upon the visible image This correction I have effected in two modes First, by constructing a double objective of flint and crown glass with such curves as will produce the correction, second, by applying to an ordinary achromatic objective a lens of such curves and density as will produce the required correction Of the first description is

the objective of $11\frac{1}{4}$ inches' aperture described by me in the May number of the American Journal of Science for the year 1865, and now the property of the National Observatory of the Argentine Republic.

Of the second description are the 13-inch objective now mounted in my observatory, and the $6\frac{1}{4}$-inch prepared by Mr. Fitz for the United States Coast Survey expedition to Catania to observe the eclipse of December, 1870.

Without a proper correction, the photographic images are without sharpness, and consequently entirely unfit for measurement.

TUBE AND FOCUS.

With an objective of the above description it is not possible to adjust the focus by the eye, and if it were, it would not be desirable, as the eye submits readily to such changes of focal adjustment as would be fatal to any precision in the value of a given space on the plate. The focal adjustment must be fixed by trial, and there must be a micrometer screw so arranged that the true position of the focal plane once found, it may be recovered at will. It will not do to trust to the unequal expansions by moisture of a wooden tube. I use galvanized iron neatly painted, and provided with three thermometers, by the mean of whose readings the focal adjustment is made according to a table founded upon the reading of the focalizing screw at a given temperature, and the recognized co-efficient of expansion of iron.

I find that the stars furnish the best means of determining the focal adjustment. On the same plate, side by side, images may be taken of the same stars in several different planes, and the best selected; if then the atmosphere be good, and on repetition the same point is selected, it may safely be adopted as the true focal adjustment for the existing temperature of the tube.

THE CAMERA-BOX.

This is so arranged that a plate-holder may be inserted and a picture taken at the focus of the objective. The size of a picture of the sun so taken is about one-tenth of an inch for each foot of focal length of the objective, and is too large to permit an instantaneous and uniform exposure. Such a picture would be useful during a total eclipse, and for verifying the truth of the enlarged picture as hereafter mentioned. The image of the sun at the focus of the objective is enlarged by a photographic camera-lens of ordinary construction. (I use for my 13-inch a Harrison $\frac{1}{4}$-plate portrait-tube.) No doubt a better form of enlarging lens could be devised, with a flat field, and corrected for photographic rays alone; whereas the best portrait combinations have considerable curvature of field, and profess only to unite the photographic and visual rays, a compromise which sacrifices about one-half of the sharpness of each. As yet, however, I have not seen such a lens.

After traversing the enlarging combination, the rays cross on their way to the conjugate focus, where the enlarged picture is taken. The point where the rays cross is so small that a very simple and extremely light snap for instantaneous exposure is rendered possible, while an additional and very important advantage is secured in that the whole image is simultaneously exposed and cut off.

In the camera-box, and directly in front of the exposed plate, a very fine platinum wire is stretched in the direction east and west, with a simple adjustment by means of which it can be made to coincide with the course of a star or a sun-spot traversing the field by the diurnal motion of the earth The shadow of this wire, if truly placed, will indicate, by a fine line on the photograph, the zero of position

Of course, this presupposes that the equatorial mounting is accurately adjusted to the meridian and altitude of the pole, and that the result is corrected for refraction in case the pictures are extra meridional Behind the exposed plate is to be mounted, in a slide, easily and smoothly movable from east to west, like the eye-piece of a transit, a Ramsden eye-piece capable of commanding the whole plate, from side to side, for the purpose, as hereafter mentioned, of establishing the angular value of any linear space of the plate In order to avoid unnecessary distortion of the image, the following adjustments are required

1st Collimation of the objective This is obtained by means of screws for that purpose, penetrating the rim of the objective, turned in such directions and quantities that the several images of a candle-flame held at a small hole in the middle of the plate-holder, and reflected from the several surfaces of the objective, shall be seen superimposed by an eye looking through the blue, transparent part of the flame near the wick

2d The collimation of the plates This adjustment, of more importance than the former, is attained by means of screws acting upon the guides or slides for the introduction of the plate-holders The operation of collimation is the same for each plate-holder, except that, of course, in the case of the one most distant from the objective, the enlarging-lens must be removed during the act This act consists in placing in the plate-holder occupying the position subsequently to be occupied by the sensitive-plate a plate of plane glass, smoked on the side away from the objective, to destroy reflection from that side, covering it with a screen of black paper having a hole one-quarter of an inch in diameter through which the center only of the plate is exposed to the objective; covering the objective with a cap perforated with a hole in the center one-quarter of an inch in diameter, then holding a lighted candle in front of the last-mentioned hole, and operating upon the adjusting-screws until the light of the candle, reflected from the center of the plate, is seen through the center of the objective, thus indicating that the plate is perpendicular to the optical axis of the telescope

3d Collimation of the enlarging-lens This adjustment is to be effected by means of screws arranged for that purpose, to be operated until the several images of a candle-flame, transmitted through a small hole in the center of the cap, over the objective, reflected from the several surfaces of the enlarging-lenses, are seen by an eye held behind the flame to be superimposed

The quantity and direction of the inevitable distortion is ascertained in two ways

1st By placing in the focus of the objective a plate of plane parallel glass upon which a reticule of lines is engraved, turning the instrument, focalized accurately, upon a bright sky, and taking an enlarged photograph of the reticule The reticule and the enlarged photograph are then to be accurately measured, when a discussion of the results of these measurements will reveal the distortion produced by the enlarging-lenses

2d method—and this also is the best means of determining the angular value of any space upon the enlarged photograph:

Place in the position of the plate for the enlarged picture a plate of plane parallel glass, upon which a reticule of lines is engraved, running north and south, about three seconds of equatorial time distant from each other. Clamp the telescope firmly near the meridian, and cut down the aperture to about an inch, with which reduction the definition of a large star is quite good, notwithstanding the photographic correction and focal adjustment of the objective. Then, by means of a chronograph, take transits of many different bright stars over all the lines of the reticule, observing them through the eye-piece mentioned above. A comparison of these transits with the measured intervals between the lines will give not only the angular value of a given space on the plate, but the amount of distortion produced by the instrument, objective and enlarging-lenses included.

A second mode of ascertaining the angular value is to photograph a known object at a known distance, such as a building by day, or two electric lights expressly arranged at night, or a group of stars, like the Pleiades, whose distances have been well ascertained, and deduce the required value from a measurement of the photographs.

By a combination of these methods, I think the angular value of a given linear space on the plate may be ascertained with a degree of accuracy which, if not perfect, is at least superior to that in use for any filar micrometer, or other method of astronomical measurement.

After the photographs have been obtained, with all the precautions a careful foresight can suggest, it is important that no reliance should be placed for precision upon the apparent outline of the sun at any isolated point.

The photograph of the sun will have a greater or less diameter by many seconds of arc, according to the energy of the rays which have produced the image; and this discrepancy may be produced by a change in the aperture, in the length of the time of exposure, in the transparency of the atmosphere, in the hour of the day, or in the sensibility of the chemicals.

Perhaps you will be tempted to say, if this be true, what reliance can be placed upon the results of photography? I should answer, that the sun has no sharply-defined outline, even to the eye, but, in its best state, is an irregular, seething, ever-restless object, utterly unfit to be the starting-point for measures of precision; and that, while the eye is confined, in its attempts at measures, to some small part of the sun's limb, the photograph of the whole sun can be placed upon the stage of the micrometer, and accurately centered with reference to the average of the whole contour, and thus escape the errors sure to be the result of measures based upon local bisections. The image of Venus ought to be sharp and capable of easy and accurate measurements. Its place should be compared with the center of the sun, and not with the limb.

The Coast Survey have the telescope which was prepared for photographing the eclipse at Catania. It is provided with camera, enlarging-lenses, and snap, and perhaps it would be better for the committee, before ordering another, to experiment with that. For the purpose of the transit of Venus, it would not be necessary to have an

objective larger than four inches, at the same time I would not counsel a smaller one First That size would be required to make the star-photograph needed for a fine correction of the objective, secondly, if the day of the phenomena should chance to be smoky, with too small an objective the occasion might be lost

In conclusion I would say that I have not seen enough of other proposed modes of applying photography to the transit of Venus, to judge of their merits, and that if it be the wish of the committee, I shall be glad to superintend any constructions or experiments in this direction they may please to indicate, and to initiate any observers or operators named for that purpose, in the details of sun photography as practiced in my observatory

I am, very respectfully and truly, yours,

LEWIS M RUTHERFURD

Admiral B F SANDS, U S N

IV

Letter of Mr Rutherfurd to Rear-Admiral Sands, describing the form of instrument which he considers best adapted for photographic observation of the transit of Venus

175 SECOND AVENUE, NEW YORK,
February 11, 1872

DEAR SIR The commission on whose behalf you wrote to me are at perfect liberty to make any use of the letter I wrote you which, in their judgment, may be most for the advancement of the objects with which they are charged

If the whole matter of ordering instruments for the photographing of the transit of Venus were in my control, with my present lights, I should have an achromatic objective of five inches' aperture, and seventy inches' focus, in a cell which would allow of the application, in front of it, of a lens of flint-glass of such curves as would shorten the focal distance (for photographing) to sixty inches At the proper point I would place between the two distances an enlarging-lens so constructed that the normal image of the sun in the principal focus (then about half an inch) would be enlarged to two inches at the distance of ten inches from the principal focus, viz, at 70 inches from the objective The camera box and tube should be one tube, and the focalizing rack and screw should be located at the objective end of the tube, thus simplifying the whole arrangement and permitting the use of braces, from end to end, to prevent flexure, and on taking off the photographic corrector, and taking out the enlarging-lens, the instrument will be all ready for vision On consideration, I do not think I would counsel a smaller telescope than the one I have named

I am, &c,

LEWIS M RUTHERFURD

Admiral SANDS, U S N

V

On the Application of Photography to the Observation of the Transits of Venus By Simon Newcomb, Professor of Mathematics, United States Navy

The proposed methods of observing the transits of Venus may be divided into two distinct classes The first consists in fixing the moment at which the planet is in contact with the limb of the sun, the second consists in determining the relative position of the center of the planet and the center of the sun as often as possible during the transit

Only the first method has hitherto been actually used, and, until lately, it was tacitly considered the only one practicable I conceive, however, that astronomers are growing more and more distrustful of it, and that a large majority will agree that it cannot be safely depended upon until some method is found to guard against the errors to which experience shows it to be subject The object of the present communication not being to discuss this method, I will merely ask leave to remark, in illustration of its uncertainty, that a comparison of observations of external contact in late transits of Mercury shows that these observations, which have been almost entirely neglected, on account of their supposed uncertainty, are really of the same order of accuracy with those of internal contact, on which reliance has hitherto been exclusively placed Moreover, recent researches on the physical constitution of the sun lead to the suspicion that the photosphere is subject to changes of level which might seriously impair the accuracy of the results deduced from the most perfect observations of contact

Among the proposed methods of determining the angular distance of the center of Venus from that of the sun, photography holds a prominent place It is now proposed to examine some plans which have been suggested for this application of photography, and to devise that combination among them which seems most likely to lead to the desired result The objects to be attained may be summed up as follows

1 To form an image of the sun with Venus on its disk, of such a kind that, from the outlines of the images, the points on the photographic plate, which correspond to the centers of the two disks, can be fixed with a high degree of precision

2 The linear distance between these points being determined in millimeters, or other units of length, by means of a micrometer, we must have the means of deducing the angular distance to which this linear distance corresponds, or, we must know the value of one millimeter in seconds of arc on each part of the photographic plate, and in each direction

3 We must have a fixed line of reference on the plate, from which we can deduce the angle of position of the two centers, relatively to the circle of right ascension passing through the sun's center

ACCURACY REQUIRED IN THE MEASURES

If any error in the data of measurement affected the parallax only in the ratio it might bear to the whole distance measured, the determination of the angular value of a millimeter on the photographic plate would not involve any serious difficulty But

the distance of centers, which is the quantity to be measured, being fifty times greater than the mean effect of parallax at the different stations, the latter will appear as a difference between two large quantities, and any error affecting the whole distance measured in a given ratio will affect the parallax in a ratio fifty times as great. To estimate the degree of accuracy which it is desirable to obtain, we should know what degree of accuracy a measure on the photographic plate admits of. This is a point on which we have no exact published information, but it is understood that the measures of the photographs of the eclipse of 1869 indicate that the probable error of a negative as measured is but a small fraction of a second of arc. We have some reason to hope that the probable accidental error of a determination of the distance of centers from a single negative will be less than half a second. It is probable that two hundred negatives can be taken at each station. Granting this, we may hope that the probable accidental error of the mean of all the measures at one station may be as small as $0''.03$. It is desirable that the constant errors peculiar to the station or the instrument should be but a fraction of this amount, say, $0''.02$. The least distance of centers being, on the average, about $800''$, it is desirable that the measures should not be affected with any constant error which will probably exceed $\frac{1}{40,000}$ of the entire space measured. And, considering the accuracy with which the solar parallax can be found by other methods, we are justified in pronouncing it necessary that the errors at no one station rise to the $\frac{1}{10,000}$ of the distance measured.

This reasoning applies only to the errors which are peculiar to each station. Any error common to all the stations—as, for instance, a wrong value of the micrometer with which all the measures of the plates are made—may be greater in the ratio which the entire distance of centers bears to the maximum effect of parallax in changing that distance, multiplied by the square root of the number of stations. Roughly speaking, the probable error may be ten or twenty times greater.

To secure a corresponding degree of accuracy in the determination of the angle of position, we divide the admissible probable error of relative position by the sine of the mean distance of centers, which is about $\frac{1}{210}$. If, as before, we take $0''.02$ as a limit within which it is desirable to keep the probable error at each single station, and $0''.06$ or $0''.07$ as a limit which the possible error should not exceed, we have $5''$ and $15''$ as the corresponding rough limits for the error of angular position.

SIZE OF IMAGE ON PLATE.

It is assumed that the photographs must be taken by the "wet-plate" process. When thus taken the oxide of silver, which forms the visible film, is precipitated, not as a continuous film, but in the form of minute scattered grains, which, in the few negatives that I have examined, will bear a magnifying power of only about five diameters, for the purpose of measurement, corresponding to an effective distance from the eye of about two inches.* The apparent size of the negative, as seen through the microscope used in measuring it, should, we may suppose, correspond to a magnifying power in a telescope of at least 240. To effect this with a power of five on the micrometer microscope, the absolute diameter of the negative must be as great as that formed in the

*Since this was written I have found that with good collodion the grains are very much finer than this, and will bear a power of 50. But the negatives seem to be affected with errors, of which the character is still obscure, and which prevent the use of a high power in measuring.

principal focus of a telescope 40 feet long. A yet larger negative would offer some advantages, but the attendant disadvantages would increase in so large a ratio that we may fix upon this size as being at least very near the highest limit which it will be found most advantageous to adopt. The diameter of the solar image on the photographic plate would then be four and a half inches, and that of Venus three-tenths of an inch.

On the other hand, if it be found that a negative will bear a higher power than I have assumed, a smaller image may be found equally advantageous. The test consists in the relative sharpness of the images; if it be found that a 2-inch image can be measured with twice the accuracy of a 4-inch one, it will answer an equally good purpose.

MODES OF FORMING THE SOLAR IMAGE TO BE PHOTOGRAPHED.

To take the photograph, we must either have the telescope so long that the image formed in the principal focus shall be large enough for the purposes of measurement, that is, the telescope must be nearly or quite forty feet long, or we must magnify this image by a second system of lenses. By the first method, the telescope will be too long and unwieldy to be pointed at the sun; we must therefore adopt the method devised by Professor Winlock, which has been in successful operation for several years at the Harvard College Observatory, and which has been independently proposed by M. Faye, of the French Academy of Sciences. It consists in placing the telescope in a fixed horizontal position, while the sun's rays are thrown into it by a heliostat placed in front of the object-glass. It seems to me that this method offers a number of decided advantages over the other, which I shall briefly enumerate.

1. It gives an image free from all distortion except such as can be accurately determined and allowed for.

2. Granting that the plane surface of the reflector can be preserved, it affords the most direct and certain means of determining the linear value of the second of arc on the photographic plate. For this purpose, it is only necessary to know the exact distance of the photographic surface from the optical center of the object-glass.

3. It affords the means of determining the angle of position of the two centers with great certainty.

4. The slide which receives the plate-holder, instead of being attached to the eye-piece of a moving telescope, may be firmly fixed on a stone pier in the dark room.

I now ask leave to describe the appliances and methods by which the determinations are to be made on this system, considering every objection which I have heard of, or can anticipate, and comparing the operations with those necessary in the other method.

THE HELIOSTAT.

If the reflecting surface of the heliostat be warmed by the rays of the sun, or if the two surfaces of the reflecting plate are from any cause whatever unequally heated, bad effects will be produced in two ways:

1. By changing the position of the effective optical center of the objective, and thus vitiating the determination of the angular value of the millimeter on the photograpic plate.

2 By blurring the image formed in the focus of the objective

In considering the first effect, it is only necessary to take account of the rays which pass through the optical center of the glass The problem is, two rays from points in the heavens at the angular distance γ strike the reflector, of which the radius of curvature—supposed very great—is ρ, so as to meet after reflection near the optical center of the objective—to find the difference between their directions, which we call γ', after leaving the reflector The latter is, in fact, the angle which will be given by the measure on the photographic plate, the former the actual angle we want Let us put

S, the distance apart of the points on which the rays strike the reflector

A, the angle which the line joining these points makes with the plane normal to the axis of the telescope

D, the mean distance of the mirror from the objective

$\delta\gamma = \gamma' - \gamma$, the error produced by the curvature of the mirror in the result of the angular measurement

Then, $S = D \sin\gamma \sec A$

$$\delta\gamma = \frac{2S}{\rho} = \frac{2\,D \sec A}{\rho} \sin\gamma$$

The angle A may range between 0° and 50°, rarely if every approaching the latter limit, so that for our present rough estimates, we may suppose sec A to be unity Since we desire to measure the angle γ without any probable error exceeding the $\frac{1}{40\,000}$ of its value, it is desirable that we have

$$\frac{\rho}{D} > 80{,}000$$

And, since it is necessary that the error should certainly be within a limit four times as great as this, we must have

$$\frac{\rho}{D} > 20{,}000$$

It will probably be found that at most of the stations the reflector can be placed within a foot of the objective If so, the limit outside of which the radius of curvature of the reflecting surface will be unimportant, will be 80,000 feet, and that within which it will be inadmissible will be 20,000 feet

As to the effect on definition, we remark that if the objective be of 5 inches' aperture, the effect of the smallest of the above curvatures of the mirror will be that the geometrical image of a celestial point in the stellar focus will be a disk not far from 2″ in diameter, which again will not be far from twice the enlargement due to diffraction We may therefore regard a radius of 80,000 feet as expressing the limit of admissible curvature in the reflector If the curvature cannot be kept within this limit, or if any small deviations without it cannot be determined with certainty, a serious and perhaps fatal objection will arise to the proposed plan The practicability of attaining this desideratum is the first thing to be determined, and it can be determined only by trial and experiment I conceive that it may be found practicable if proper precautions are taken The most necessary precaution and the only one which need be expressly mentioned here, is, that the reflector should be exposed to full sunlight only at the moments of taking the picture When it is found necessary to use the reflected light for adjustment, the heat rays must, as far as possible, be cut off by a blue or green glass The necessary time

of full exposure of the mirror need not be more than half a second, or a second at most, for each picture. At the rate of one picture per minute, the latter would be only one-sixtieth the whole time.

Though not absolutely necessary, it is very desirable that the reflector should be moved by clock-work. The most perfect arrangement would be that of the "siderostat" of Foucault, in which the mirror is moved around two axes in such a manner that the reflected rays remain parallel as the sun passes along its parallel of declination by its diurnal motion, the change due to refraction excepted. Since the latter will be considerable when the sun is near the horizon, and will necessitate occasional adjustment of the reflector even with this complex mounting, I think it will be best to have the mirror move around a single adjustable axis. The adjustment must be made so that the direction of the reflected ray shall vary from that of the telescope the least possible during the transit. The whole base on which the mirror and its clock-work rests must be furnished with two slow-motion adjusting screws, the one for altitude, the other for azimuth. These screws are to be moved by rods running the whole length of the telescope, and terminating in handles near the operator. Whenever it is found that the center of the sun's image is deviating from its proper position on the plate, the operator will pass the sun's rays through the green glass screen, and adjust the image by the screws at his side.

The construction of the clock-work will involve questions of detail which need not be examined here. It is, however, advisable to remark that the motion of the mirror must be free from all vibrations, and that every instrument must be carefully tested for this condition before being used. The most certain test will be to mount a powerful microscope on a fixed and firm support, in such a way that it shall view a Nobert's test-plate attached to the axis of the mirror at a distance of, say, one foot from its center of motion.

This method will be attended with practical difficulties which may prove insuperable. The following arrangement will be much more simple, and may prove equally certain. Take a strip of metal or wood one or two feet in length, and a few inches in breadth, with a smooth, white surface, and rule it cross-wise with very fine black lines. Perhaps a coarsely-ruled glass, with a nearly monochromatic light behind it, will be better. Place this strip with its lines vertical, and its surface presented to the mirror, at a proper distance from the latter, at a time when the air is very steady. Make the axis of the mirror vertical, and the mirror itself parallel to it, in such a way that the ruled plate can be seen by an eye-piece in the photographic telescope. Then start the clock-work which moves the mirror, and note whether the dark and bright lines on the plate are equally well defined, whether the mirror is at rest or in motion. A great improvement will be to move the ruled strip with the mirror in such a way that the direction of the reflected rays shall remain constant. With regard to the coarseness of the lines and the distance of the plate, it may be remarked that the test will not be satisfactory unless the angular distance between the lines, as seen from the mirror, is much less than a second of arc, and that they must be viewed with the highest power the atmosphere will bear. The trial-plate might be ruled with 150 lines to the inch, and then viewed at as great a distance as it is possible to see the lines.

To avoid all serious danger of vibration, I would propose that no toothed wheels

shall be allowed in the moving-machinery, but that all motion shall be communicated by fine and well-oiled tangent-screws

Whether the mirror should be of plain glass, silvered glass, or speculum metal, is a question of detail to be settled by experiment The primary condition is that there shall be no danger of warping under such influences as it may be exposed to at the observing-station, and I conceive this condition will be fulfilled by plain glass The time of exposure will be materially affected if this be chosen, since only a small fraction of the light will be reflected down the telescope The question of having the mirror moved by clock-work is also indirectly affected by it, in this way If a speculum be used, the time of exposure may possibly be made so short that the elongation of the image by the diurnal motion during that time shall be of no importance, but if plain glass be used, this short exposure is no longer possible, and clock-work must be used

THE OBJECTIVE

The object-glass must be corrected, not for the visual, but for the photographic rays

As it is necessary to take every precaution to have the photographs at opposite stations strictly comparable, it will be well to have all the glasses made from the same pot, and ground on the same tools If the former cannot be effected, the optician should endeavor to have all of a uniform focal length

The aperture of the glass cannot be fixed by any rigorous principle The larger the glass, the less the enlargement from diffraction This enlargement is, however, equal in every direction, and will not affect the positions of the centers of the images on the plate If too great it may, however, affect the definition of the image. Probably an aperture of five or six inches will be found the most advantageous mean With a metallic mirror the brilliancy of the solar image on the plate will not differ much from that of direct sunlight If the mirror is of glass the brilliancy will be very much less

I have already given my reasons for holding that the focal length of the object-glass should not differ very much from forty feet, being greater rather than less Whether an image of a greater diameter than four and a half inches can be photographed without inconvenience, is a question for the professional photographer, and on his answer will depend the advisableness of having a longer focus to the objective

The objective must not be supported by the tube, but must be held by some firm support let into a stone or brick pier, large enough to support the reflector also Its cell must be furnished with two sets of adjusting-screws, so that the optical axis of the glass may coincide with the terrestrial meridian line

A line, from which measurements may be made, must be cut around the outer convex edge or cylindrical surface of the cell This line will form a circle, in or near the plane of which the optical center of the glass will be found Care must be taken that the cells are all of the same dimensions, and that the lines cut on them all correspond in position

THE TUBE

As it is doubtful whether the definition of the image will be improved by the tube, the principal object of having one will be to cut off extraneous light If one is

used it must be as large as convenient, and must be in sections, not only for convenience in transportation, but that it may be partly or wholly removed for the purpose of measuring the distance between the line on the cell of the objective and the face of the photographic-plate. For this purpose the two ends may be made of black cloth. It must be carefully screened from the direct rays of the sun, and at the southern stations it may be found advisable to pass it through some part of the observatory building.

ARRANGEMENTS AT THE FOCAL POINTS.

The focal point where the pictures are taken must be due south from the objective, except, possibly, at the extreme southern stations, where it may be north; the choice of directions being determined by the condition that the mean angle of reflection of the rays must be acute, so as to diminish, as far as possible, the evil effect of any sphericity of the reflecting surface. Here a brick or stone pier must be erected to support the plate-holder. The position or form of this pier must be such that a plumb-line may be suspended so as to pass through the central point of the focus. It will therefore be necessary either to place the pier so that its inside face shall be slightly beyond the focal point, or to build it on an arch, and to have a small, vertical hole passing through its center, and opening into the arch below. The latter form is the more satisfactory and complete, and if the pier is built of brick or concrete, will be little more troublesome than the other.

On top of the pier in the latter form, or above the inside face in the first form, must be fastened the frame which is to receive the plate-holder. From the top of this frame is to be suspended a weight by a very fine platinum wire. The general arrangement of the frame and the plate-holder must be such that the wire shall be as close as possible to the face of the negative when the picture is taken, while, at the same time, the plate-holder can be inserted, and the negative exposed and withdrawn without danger to the wire. The mechanical details by which this is to be effected do not seem to involve any difficulty, and they need not therefore be considered at present. I conceive that, by a proper construction of the plate-holder and frame, the distance between the wire and the face of the plate need not exceed one-eighth of an inch, and the former will then be photographed very finely on each negative.

A source of danger to be guarded against will be the want of perfect flexibility in the wire, and a possible consequent deviation from the true vertical. This must be a subject of careful investigation. If such a danger be found real, it may be reduced to a minimum by attaching the wire not immediately to the frame, but to the lower end of a stout vertical pin passing through an opening in the top of the frame. The verticality of this opening must be tested. The top of the pin must be provided with a graduated head, so that it can be turned into any required position, and the position must be frequently reversed while the photographs are being taken.

A horizontal wire must also be stretched across the frame, so that it shall be photographed on the plate, the point where the two wires cross marking the center of the field. It is necessary that the center, as thus indicated, shall be south and horizontal from the optical center of the object-glass without a probable error so great as $10''$, or, in other words, without a probable error in its absolute position so great as $\frac{1}{50}$ of an

inch This may be conveniently effected by mounting the instrument or instruments by which the time and latitude are to be determined in front of the photographic object-glass, and at the same elevation Then, by pointing the transit instrument on the glass, the vertical wire can easily be set with far more than the requisite precision If a meridian circle be used instead of a simple transit the horizontal wire can be set with equal ease and precision If not, some other method must be devised, of which the most simple is, perhaps, to make the finding circle of the transit instrument large enough to read every 10″ of arc, and then to make a number of comparisons of the reading of this circle when set on known stars and when set on the horizontal wire Other more simple methods may perhaps be devised

EXPOSING THE PLATE

We now touch another point which involves some mechanical difficulties Every part of the negative must be equally exposed, else the picture will be more developed on the more exposed side The time of exposure being only a small fraction of a second, the slit through which the sunlight is admitted must be very narrow unless it moves with great rapidity Equal exposure of every part of the picture will be perfectly attained by cutting off the light at or beyond the object-glass But two difficulties arise here The image will be elongated by diffraction in a direction at right angles to the slit, and the apparatus will be too far to be easily at the command of the operator Although a small elongation by diffraction will not be very serious, since it will not affect the center of the image, yet I think it desirable to avoid its becoming so large as that due to a narrow slit in front of the objective It therefore seems desirable, if not absolutely necessary, to bring the cut-off within one or two feet of the focus Here another difficulty arises If made and operated in the usual way, the slit will move over the plate with an accelerated velocity, and thus the last part of the plate which it reaches will be less exposed than the first We must, therefore, contrive some way by which its motion shall be nearly or quite uniform as it passes over the plate Various ways of effecting this may be contrived, I suggest the following, as showing the entire feasibility of the operation

A, Fig 3,* is a thin disk of papier-maché, or other light material, mounted on a stand after the fashion of an electrical machine Three feet would, perhaps, be the best diameter It is attached to a solid, shallow hub, concentric with it and from 6 to 8 inches in diameter A groove is cut round this hub, and a rope or metallic ribbon, bearing a weight, is attached to some point of the groove The length of the rope is such that the weight shall just rest on the ground, or some support, when near its lowest point, and shall also allow room for the weight to be wound up by nearly the amount it will be raised by one turn of the wheel Between the disk and the hub is a small disk, rather larger than the latter, around which are five or more ratchet teeth, *t*, *t*, *t*, *t*, *t* Two catches, *c*, *c′*, can hold these teeth in opposite directions The wheel is to be set so that its plane shall be vertical, its axis at the same height with that of the telescope, and distant about 12 inches from it, so that the outer 6 inches of the disk shall cut off the cone of rays near the focus The circle T shows a section of the tube,

* The figure has not been engaved, as the general principles of the apparatus proposed can be understood from the description in the text

as projected on the disk. D is an adjustable opening in the disk, the sides of which should be radii of the disk. As the instrument is now represented, the cone of rays is intercepted by the disk at T. To expose the plate, the operator raises the catch c, whereupon the weight descends and carries the disk around with a velocity continually accelerated until the weight rests. This should occur just before the opening D reaches T. The disk is then carried forward by its own momentum, so that D passes over T with a velocity quite uniform, the retardation due to friction excepted. The disk still moves on by its own momentum, lifting the weight until one or more of the teeth, t, t, t, pass the catch c', which holds them and prevents the weight carrying the wheel back after it has reached a state of rest. To take the next picture, the operator will continue to turn the wheel in this same direction until the catch c' hooks the tooth t_5, when the opening D will be just above T. The catch c will then be dropped, and the apparatus will be ready to expose the next picture by a motion in the opposite direction. The effect of the small retardation of velocity will thus be reversed in taking every picture, and eliminated in the mean of any two consecutive ones.

Perhaps it will be advisable to have an opening 6 inches in diameter through the disk at T, covered by a plate of glass nearly opaque to the photographic rays, by which the observer may examine the position of the solar image on the ground glass plate as often as necessary.

DETERMINATION OF THE POSITION OF THE PLANET ON THE SUN'S DISK.

Having thus described the apparatus with which the photographs are to be taken, we have next to consider the means by which, from the measures on the plate, we can deduce the distance and angle of position of the centers of the sun and Venus, as seen projected on the celestial sphere, and to inquire how these means compare with those afforded by the other proposed method of photographing, in point of certainty, accuracy, and convenience. As remarked at the beginning of this paper, two data are required:

1. The angular value of one millimeter on the photographic plate at any point and in any direction.

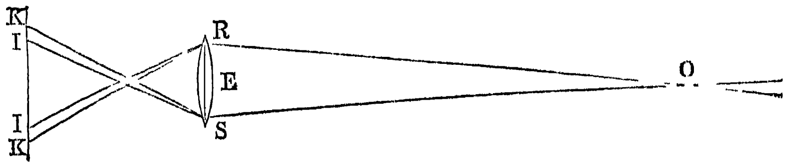
2. The angle of position on the celestial sphere corresponding to some line ruled or photographed on the plate.

To obtain the first element the observer must, when the objective and plateholder are all firmly fixed in their definitive positions, carefully measure the distance between the inner face of one of the photographic plates and the inner face of the objective, or the line drawn around the cell or, for security, both. The temperature of the measuring-rods must be carefully noted during the measure. The temperature of the plates, at the time the photographs were taken, must also be known within 3° or 4° Fahrenheit. Having these data, which include everything necessary to deduce the corrections for temperature, knowing also that the face of the plate was sensibly perpendicular to the axis of the telescope, we have everything necessary for a quite precise determination of the required element, *independently of the question whether the plate was accurately in the focus of the objective.* The value of any measure on the photographic plate is equal to the angle subtended by that measure at the distance of the optical center of the object-glass. It is true that the optical center thus defined

will not be precisely the same for all points of the plate, nor even for different directions at the same point But, these small deviations must admit of very accurate calculation from the known forms and degrees of refrangibility of the glasses which form the objective Any small uncertainty which may still remain will, as already remarked, be much reduced if all the telescopes are of the same pattern

If we adopt the other system of photographing in which the image is enlarged by a lens, it will be necessary to have a ruled plate in the principal focus, the lines on which shall be photographed on the sun's disk in every picture, and to refer the measures of each picture to these lines The angular distance of these lines must therefore be determined with the same degree of precision already fixed for the photographic measures, that is to say, it is desirable that the probable error of the angular distance shall not exceed $\frac{1}{40,000}$ of the whole, and necessary that its possible error should not exceed $\frac{1}{10,000}$

It will be entirely inadmissible on this system to trust to any determination of the angular value of a given measure on the negative, because this value will, in the case of an enlarged picture, *depend on the refrangibility of the light which forms the image* This will be made evident by an inspection of the following figure



Let O be the optical center of the object-glass, and E the enlarging-lens, the principal image being formed between E and O For our present purpose it is only necessary to consider the rays which pass through the optical center of the glass Let O R, O S, be the central rays from two objects whose angular distance, R O S, is to be determined by the linear distance of their images on the plane of the secondary focus K K It is evident that the rays from the upper object passing through the lower part of the enlarging-lens will all be refracted upward to form the second image, and that the image formed by the more refrangible rays will therefore be higher than that formed by the less refrangible ones In the same way the image of the lower object formed by the more refrangible rays will be lower than that formed by the less refrangible ones Hence, if a reticule be extended along the secondary focus, space K K for the more refrangible rays, and I I for the less refrangible ones will correspond to the same celestial arc, R O S Hence the distance of the wires will have no definite geometrical value, but each ray of the spectrum will have its own value

It is true that if we had a perfectly achromatic combination which would refract all the rays geometrically to the same point, this difficulty would be entirely avoided But it is very well known that no such combination is possible, and the outstanding uncertainty in the best possible combination will, I conceive, exceed the uncertainty in the present adopted values of the solar parallax

It being necessary to refer all the measures to a reticule in the principal focus, the problem will be to determine the angular distance of the lines of this reticule with the

requisite accuracy, the accuracy required being greater than has ever been attained in such a determination. Three modes of making this determination have been proposed:

1. By the distance apart of two images of the sun photographed at known moments, the telescope remaining unmoved during the interval.

2. By measurement of the linear distance between the lines of the reticule, and combination of this measurement with one of the distance between the reticule and the object-glass.

3. By photographing objects of which the angular dimensions are known with the requisite degree of accuracy.

To the first method there are several objections: The distortion of the images from not being in the center of the field must be greatly increased; the elapsed interval must be known within one-hundredth of a second, which may involve some difficulty; and there must be danger that the telescope will not remain absolutely fixed during the entire interval.

In the second method the principal difficulty will be to measure the actual distance between the reticule and the objective as it is at the time of photographing. This difficulty, however, is purely a practical one, and may be overcome.

The third method seems to me the most feasible. The object photographed must, however, be a terrestrial one; since there is no celestial object of which the angular dimensions can be determined with the requisite precision.

ANGLE OF POSITION.

By the proposed method the angle of position will be determined as follows: The local time being known, we can deduce the position of the sun in the celestial sphere at the moment the photograph was taken. The altitude and azimuth of the cross-wires on the photographic plate, as seen from the optical center of the object-glass, being zero by adjustment, and the co-ordinates of the sun's center on the photographic plate being known by measurement, we can determine the altitude and azimuth of the ray which, coming from the sun's center, was reflected from the mirror. Knowing the points on the celestial sphere corresponding to the direct and the reflected ray, represent them by S and S′, and join them by a great circle. The middle of the arc will mark the point of the sphere which is normal to the reflecting surface of the mirror; call this point N. Next, take a point V in the neighborhood of S, and pass a great circle through V and N. Take the arc NV′ equal to VN, and V′ will mark the direction of the reflected ray from V. The points S and S′ being known, the angle which the great circle S N S′ makes with the horizon can be computed. The vertical platinum-wire being photographed on the plate, the angle which V′ S′ makes with the horizon is determined by measurement. Thus, we have the angle N S′ V′, which is equal to N S V. The direction of N S being known, we immediately deduce the angle which the line S V makes with the horizon, which was required.

It will be seen that scarcely any of the elements on which this determination rests depend much upon instrumental adjustments, unless it be the azimuth and altitude of the photographic telescope, and this can be fixed with a degree of precision far exceeding our present requirements without serious difficulty.

I do not see how the element in question can be determined with the required accuracy by the plan of a telescope moving on an axis. I doubt whether the inclination of the wires of a meridian instrument could easily be determined without a probable error exceeding 6″, certainly it requires a long time to do so. If, in the case of the photograph telescope, the determination were accurately made on one day, it might be wrong by this amount on the day following, unless the mounting were more firm and massive than a portable instrument would admit of. If it were accurately made when the instrument was on the meridian, it might be inaccurate when the instrument was turned on the sun, through the effect of flexure and errors in fixing the directions of the axes of revolution.

CONCLUDING REMARKS

The determination of the solar parallax from measures of photographs of the sun taken during the transit of Venus is beset with this serious difficulty. That the required element appears only as a minute difference between two comparatively long arcs, much longer, in fact, than are often measured with a micrometer. In order that the solar parallax may thus be determined with a precission exceeding that attained by other methods, it is necessary that the arcs in question be measured with a precision considerably exceeding any ever attained in the astronomical measurement of an arc of similar length.

The difficulties of the operations are greatly aggravated by the direction and motion of the body to be photographed, which require the apparatus to be mounted on moving axes, and demand either an instrument of unwieldy proportions or the use of an enlarging lens.

In Professor Winlock's apparatus the diurnal motion is thrown entirely upon the revolving mirror, so that all the advantages of a fixed horizontal sun are obtained. The apparatus is all firmly mounted on stone piers, thus admitting of exact measurement of all its parts, and avoiding all danger of changing the adjustments by the photographic manipulations. It seems to be that the advantages are all greatly in its favor.

4 V